BRITAIN'S BEST SELLING ELECTRONICS MAGAZINE

No. 54

ELECTRONICS

The Maplin Magazine

JUNE 1992 £1.60

Find faults *fast* with this Signal Tracer/ Injector!

- **Another easy-to-build beginners' project**
- **Sense intruders with an IR proximity detector**
- **How to solve motor and lamp drive problems**
- **Secrets of the Boeing 747 instrumentation**

PLUS! How to... Design sequential logic circuits, Use oscilloscopes, Understand electronic ignition and video processing systems, and so much more!

CREATE A RELAXING ATMOSPHERE WITH THE EnviroSynth

See inside for details...

CONTENTS

JUNE 1992 VOL.11 No.54

EDITORIAL

Hello and welcome to another issue of 'Electronics'! As always there is a varied collection of projects and features. Featured on this issue's front cover is a particularly unusual and interesting project; The EnviroSynth is designed to recreate sounds from the environment – hence the name. The two sounds chosen are those of waves breaking on the seashore and a gently blowing breeze. These sounds have been chosen as they are often found to be soothing, and as such, may help relaxation and sleep. The unit can be used to provide a level of background 'noise' to overcome acoustically dead environments such as quiet offices, etc. The EnviroSynth also produces 'white' and 'pink' noise, which, together with the ability to tailor each of the sounds, makes the unit ideal for providing 'special effects' in drama productions, etc.
In the penultimate part of the series 'Electronics in Aviation', Chris Yates takes a look at aircraft instrumentation systems, and in particular, the changing face of the 747 series aircraft. There is the rare chance of being able to compare directly the flight-deck instrumentation systems on both the 747-200 and 400 series, with superb photographs from the Royal Dutch Airline KLM.
Finally, all that remains for me to say is I hope that you enjoy reading this issue as much as the 'team' and I have enjoyed putting it together for you!

ABC 31,125 Jan-Dec '91

Editor Robert Ball
Project Development Chris Barlow, Gavin Cheeseman, Tony Bricknell, Alan Williamson.
Technical Authors Mike Holmes, Martin Pipe.
Consultant Author Alan Simpson.
Technical Illustrators Paul Evans, Lesley Foster, Ross Nisbet, Nicola Hull.
Production Co-ordinator Alan Wraight.
Print Co-ordinator John Craddock.
Advertising Co-ordinator Kathy Peters.
Publications Manager Roy Smith.
Development Manager Dave Goodman.
Advertising Manager Vic Sutton.
Drawing Office Manager John Dudley.
Art Designers Peter Blackmore, Jim Bowler.
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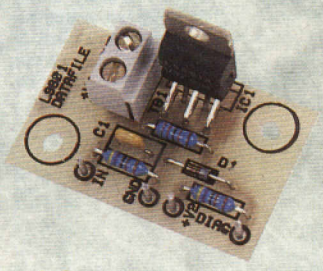
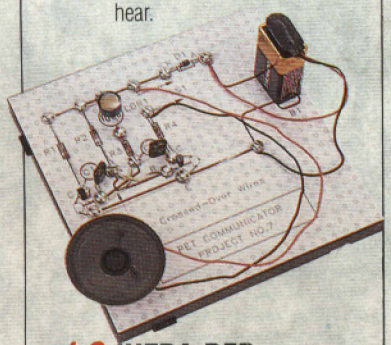
PROJECTS

16 ENVIROSYNTH
Designed to create soothing background sounds, like waves breaking on a seashore or a gentle breeze.

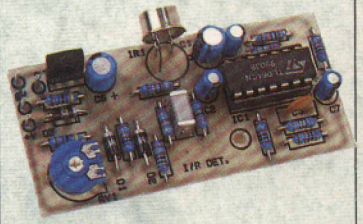
32 DATA FILE: HIGH SIDE DRIVER
How to use the L9801, a purpose designed driver IC.



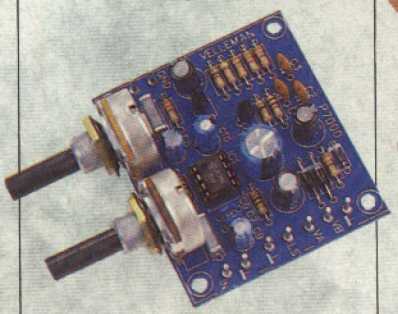
40 FUNTRONICS: PET COMMUNICATOR
A device that emits high-pitched sounds that pets can hear.



48 INFRA-RED PROXIMITY DETECTOR
This compact unit is ideal for use in security applications.



67 SIGNAL INJECTOR/TRACER
Fault-finding on analogue audio equipment is made much easier with this low-cost, easy-to-build, project.



FEATURES

4 ELECTRONICS IN AVIATION
The penultimate part deals with aircraft instrumentation systems.

10 SEQUENTIAL LOGIC
Serial and parallel registers are examined.

24 FINISHING OFF
How to make your projects look more professional.

36 OSCILLOSCOPES IN ACTION
How to perform AC/DC voltage and current measurements.

43 ELECTRONIC IGNITION
How automotive electronic ignition systems work.

56 VIDEO PROCESSING SYSTEMS
Synchronisation, colour decoding, field sequences and test signals are examined.

62 MODERN BRIDGE CIRCUITS
Deals with 'special' types of bridge circuits and substitution boxes.

REGULARS

2 NEWS REPORT
23 STRAY SIGNALS
31 CLASSIFIED
35 NEXT ISSUE
39 COMPETITION WINNERS
47 TOP 20 KITS
53 ORDER COUPON
54 SUBSCRIPTIONS
55 AIR YOUR VIEWS
66 NEWSAGENTS COUPON
71 NEW BOOKS
72 TOP 20 BOOKS

CORRIGENDA

March 1992. Issue 51.
Velleman K4000 Stereo Valve Amplifier
Page 8, paragraph 2. The sections of text that read: 'the cathodes are always negative with respect to the grid' and 'the cathode of the other valve is driven positive with respect to the grid' – should read, 'the grid is always negative with respect to the cathode' and 'the grid of the valve is driven positive with respect to the cathode'.

Prices shown in this issue include VAT at 17.5% (except items marked *NV* which are rated at 0%) and are valid between 1st May 1992 and 31st August 1992.

NEWS Report

On Your Zike

Clive Sinclair has come back with a bounce – or rather a bike – following his abortive introduction of the C5. Sticking to electric propulsion, the Zike electric bicycle can travel for up to an hour under its own power, reaching a maximum speed of 12mph. Until now, electric power driven vehicles have suffered a heavy weight problem because of the batteries. But Sir Clive's Zike weighs under 25 pounds including battery, electronics and motor, and is as light as a typical racing bicycle. Sinclair Research suggest that the Zike, priced at just under £500 including VAT, is designed with a wide range of uses in mind, from local commuting and shopping to leisure. The bike is pollution free, may be ridden by anyone over 14 without licence or road tax, and can be used wherever a normal bicycle may go. The Zike has three modes of operation, self propelled, pedal assisted and motor assisted pedalling. Recharging the newly developed nickel-cadmium battery takes about one hour. Just about the same time as the C4 electronic car took to travel a mile.

More Battery Power

Panasonic has introduced a new range of high power, compact secondary batteries, designed for use as memory back-up power supplies for use in telephones, microprocessors and video cameras. Virtually indestructible, the Vanadium-Lithium cells are not damaged if subjected to continuous overcharge or discharge. Even after prolonged storage, minimal discharge rates (2% per annum) make recharging unnecessary. The cells, say Panasonic, do not suffer from the 'memory' effects experienced with Ni-Cd cells. Details: (0344) 853261.

APOLOGY

'ELECTRONICS' MARCH 1992, Vol. 11, No. 51, Page 54. Figures 3, 4 and 5 were inadvertently reproduced without permission from **Longman Group Ltd.** Alan Pickard and 'Electronics' would like to apologise for any inconvenience that may have been caused.

Let's Hope it isn't True Department

Howard Rheingold, author of 'Virtual Reality' is quoted as saying "There have been some successful attempts to prove that virtual sex is a real possibility." What next? Sex by mail order?

Winds of Change

BT may be in the top ten public hate list, but it is also in the top two list of company charity donations. In the past year, BT donated over £13 million to good causes covering people with disabilities, people in need, economic regeneration, education, environment and the arts. The company now has dedicated managers up and down the country whose role is to ensure that BT's charities gets to the right community activities. Richard Worsley, director of BT's charity operation, says that "the new structure will help us put in order our community funding priorities as we have many more requests for help than we can ever cope with." BT has produced a special community edition of its charity operations 'BT Today'. For details contact Garry Hicks, (071) 356 5392.

Alarming News

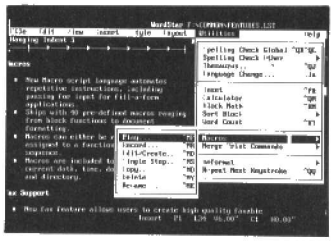
Beating the burglar should be easier after the ending by the DTI of certain restrictions on radio alarms. As a result, long-range radio alarms which previously could only serve as a back-up to wired systems provided by a PTO, can now standalone as alarm systems. With no wires to cut, LRRAs can provide a higher degree of protection than traditional alarm systems.

HDTV Bickering

On a more global level, it seems that the 1400 representatives at the month-long, World Radio Conference have been unable to arrive at a compromise for a unique frequency allocation for wideband HDTV. It was also back to the drawing board for VHF terrestrial digital sound broadcasting, due in particular to the impatience of several European countries to implement Digital Audio Broadcasting (or DAB) broadcasts.

Meanwhile, back in the UK, Radio amateurs will have access to greater power following the agreement of the DTI to make available 1·830 to 1·850MHz frequencies with a new maximum power level of 26dBW PEP (Peak Emission Power). Watch this space for further relaxation announcements.

Click into Word Processing



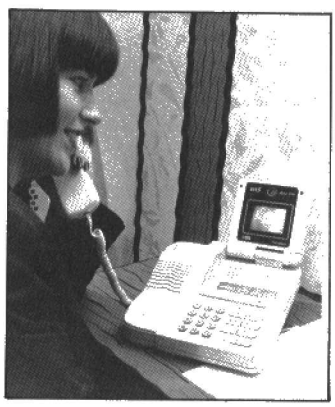
WordStar, who last year alone shipped nearly one million copies of their word processing packages, are offering their half a million UK users an easy update in window graphics. A new interface is available, aided and abetted by new levels of mouse support. WordStar 7.0 can now directly import up to 27 graphic file formats, with speedy commands and screen displays. No doubt we will be featuring competitor WordPerfect's response in a month or so.

586 on Course

Intel announced, at the Hanover CeBIT exhibition in March, that deliveries of the new 586 'new generation' microprocessor will commence soon. According to Frank Booty's 'The 486/386 Debate' (see February's 'Electronics'), a current 486DX microprocessor, running at 33MHz, will execute 27 million instructions per second (MIPS). The new chip can, in comparison, deliver around 100 million operations in the same time! As a result, machines built around the new microprocessor will work considerably faster than their 386- or 486-equipped counterparts. Features of the new IC include downwards-compatibility with the rest of the range, the ability to process two instructions per cycle, and provision for use within multi-processing systems.

According to Dave House, the Intel vice-president, the 586 is not simply destined for 'faster PCs'. It is also designed to be incorporated into more complex computers, such as mainframes and other multi-user systems.

Hear no Evil . . . See no Evil



At the Ideal Home Exhibition in March, BT demonstrated a prototype domestic videophone. However, while the concept of a home videophone remains controversial, several things remain very interesting. First of all, the BT videophone is designed to work on a single normal (analogue or digital) phone circuit i.e. 'video-calls' will cost the same as normal telephone calls. Bearing in mind that a normal PAL colour TV picture occupies a bandwidth of 5·5MHz, the fact that BT's colour videophone will work with a (often) noisy landline of 3kHz bandwidth seems nothing short of miraculous!

This seemingly impossible feat is achieved by the clever use of error-correction circuitry, advanced modulation techniques and heavy compression. In addition, the picture is 'refreshed' at a far less frequent rate than that of a broadcast television picture ('slow scan') – something that may well annoy some users.

Another more interesting fact is that the product has been developed by none other than our very own GEC-Marconi – see 'Darwin Proved Right', elsewhere in these pages. BT hopes to sell the videophone for 'less than £500'. Presumably, if the idea catches on (something which is unlikely during these recession-laden times), the price will come down – just as it has for other high-technology products. BT says that the videophone will form 'part of a portfolio of videocommunications products' that will include desktop videoconferencing, digital videophones and personal computer-based multimedia equipment. Conforming, not surprisingly, to GEC-Marconi's MTVS standard, the BT colour videophone has a small camera and a three-inch colour screen mounted on a flap, which may be folded away. It may also be used as a conventional 'voice only' telephone, as you would expect.

Meanwhile, BT has been developing a digital videophone at its Ipswich laboratories, for use on the Integrated Services Digital Network (ISDN). Although it is (no doubt) capable of better picture quality, the cost is somewhat different from the domestic unit – £2,000! In addition, calls cost more (despite compression, the bandwidth required is still large). Aimed (predictably!) at the business user, the ISDN videophone conforms to the CCITT H.261 standard for data compression.

Television for the Blind

Picasso, says the ITC, claimed that "painting is a blind man's profession. He paints what he feels, what he tells himself he has seen." Watching TV for blind or visually impaired people is rather similar. The information generated from TV is mainly sound, perhaps supplemented by what can be gleaned from the shadowy blurred images distinguishable on the screen. With some 1·7 million blind and visually impaired people in the UK, a method of 'watching' TV is obviously desirable. A new technique known as Audio Description could provide the solution. It allows blind people to hear a special commentary channel, which would explain exactly what is happening on the TV screen, rather like a friend whispering in your ear. Modern digital techniques allow the usual amount of information needed to carry a sound channel to be much reduced, meaning that it can make use of the increasingly small 'spare' parts of the TV signal not used to carry the picture. A prototype system could be available for demonstration this autumn. Given the complexity of typical TV plots, such an explanatory feature could also be of interest to the majority of normally sighted viewers!

BBC Claims to have Discovered Computers

Last month saw the BBC Computer Literacy project celebrating its 10th Anniversary. In that time, over 300,000 BBC micros (Acorns) have been purchased by schools and colleges, while a further 750,000 machines have been bought for use in research laboratories, commercial organisations, family firms and as an aid to people with physical or

mental disabilities. As Alan Rogers, head of BBC Education and Training said, "In the late 1970's, computers were still shrouded in mystery and available to only a very few. The power of broadcasting has helped make the computer accessible to everyone. Only a decade later, Britain has become one of the most computer literate nations in the world." The BBC will also claim much of the credit for furthering our understanding of computers with a new series entitled 'Computing for the Terrified.' This series is designed for everyone who is scared of computers, but want to become more technologically literate. Count the compilers of 'News Report' as among those glued to their screens when the series is broadcast early next year.

The Smallest Motor on Earth

For most 'Electronics' readers, the small (1 inch diameter) 3V motor used in a personal stereo cassette player is likely to be the smallest that they have seen. A new motor, which also runs off a 3V DC supply, was recently developed by Japanese industrial giant Toshiba, but comparisons end there – the Toshiba motor is a mere *one hundredth* of an inch in diameter. In other words, a hundred of these microscopic devices stacked end-to-end will produce a line representing the diameter of the aforementioned personal stereo motor. The micro-motor was manufactured using highly advanced nanotechnology; IC fabrication techniques and 'micro-machining'. All of the components (magnets, rotor, bearings, coil, etc.) are essentially the same as those used in conventional motors; they are just scaled down! In addition a controller IC is also included in the design. But is such a motor nothing more than technology for its own sake, the Japanese showing off their technological prowess? The answer is a resounding 'no'. Subminiature motors like these will find a multitude of uses in the medical field, for example. 'Electronics' hopes to compile a feature on this fascinating subject soon.

High Performance Film

ICI has unveiled a new high performance material for the electronic industry. Called Kaladex, the material is a biaxially oriented polyethylene napthalate (PEN) film with properties chosen to fill the performance niche between PET polyester film and the very high performance polyimide films.

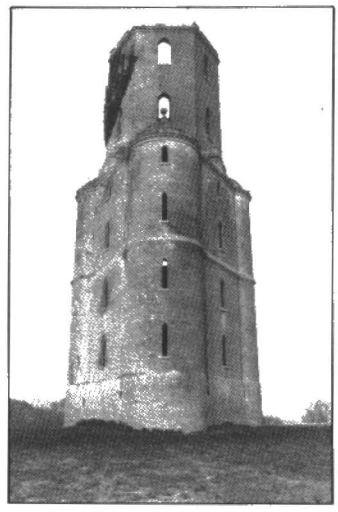
With a continuous use temperature of 155°, compared to 130° for PET film, Kaladex is well suited to electronic applications where temperature performance is an important consideration. These include flexible printed circuits, membrane switches and flexible heaters as well as high performance class 'F' electrical installation and wiring. Details: (0707) 323400.

Government Moves to Boost the Engineer

After a previous news item of ours about the plight of would-be electronics engineers, it would seem that after all a government department, the DTI in fact, are keen to further the cause of the UK engineer. Areas of industrial decline are to get a boost of over £11 million for research and development. The grant, approved by the European Commission, will help encourage small enterprises to become more involved in R&D, in co-operation with local education institutions. At the same time the DTI is encouraging the brightest and best young people to choose careers in science and engineering by producing a series of videos.

Strange perhaps that the same government department is encouraging young British engineers to go to Japan and join local engineering companies. Discounting the thought that it might be a cunning ploy to help reduce UK unemployment figures, the DTI will pay 50% of the costs, up to a maximum of 335,000 to companies willing to join the scheme and send an engineer to Japan.

Vodafone's Folly



Apart from an inability to spell its name right, Vodafone, a leading force in mobile communications, is involved in a further folly. A disused local folly called Horton Tower has been acquired, renovated and converted into a radio base station. Situated in Wimborne, Dorset, it was highlighted in Thomas Hardy's book 'Far from the Madding Crowd'. Built in 1726, the tower is believed to be the tallest folly in the country. To protect the environment, Vodafone have hidden the electronic equipment inside a cabin sunk into the ground, and even the aerials are face-mounted and colour-coded, so they blend into the façade of the building.

Tune in for a Prize

Dedicated radio buffs should turn on and tune in for the chance to become Young Amateur of the Year. The prestigious award, sponsored by the Radiocommunications Agency and Radio Society of Great Britain is open to any radio amateur under 18 who is involved in DIY amateur radio construction, operates radios and is concerned with community radio. The closing date for a cash prize is 31st July 1992. Details: (0707) 59015.

Darwin Proved Right

Many industry insiders are of the opinion that electronics companies specialising in military hardware cannot diversify into consumer electronics, the commonly stated reason for this being the maintenance of dual standards (military and commercial), which would be prohibitively expensive. Despite this, Marconi Defence Systems have, at their Broad Oak plant in Portsmouth, turned from missile-related product lines to satellite TV receiver PCBs and car alarms – requiring around £5m so far in investment. During 1992, such items will account for a turnover of over £10m. Considering that the operation has only been going since the end of 1990, and that the total turnover of the plant is around £70m, it can be judged a success by any standards.

The decision by Marconi Defence Systems was provoked by a reduction in military spending, an off-shoot of the ending of the Cold War. The company realises that switching over to commercial production keeps factories busy, and people employed, until such time as the demand for defence-related products increases again. At this time, the company plans to increase its commercial operation; it is aiming for around 30% of total turnover by 1995.

However, this story is not without its ironies. Marconi's parent company, GEC, was once a household name in consumer electronics – as, indeed, was Marconi itself. Both switched from this field during the seventies as the Japanese started making in-roads into traditionally 'home-grown' industries.

Twenty years later GEC-Marconi are using lessons, learnt during their love affair with the military, to compete with the Far East – lessons on consistent quality, efficient production engineering and effective management. It is a sad fact that the potential of these philosophies, originally conceived in the West, was realised by Japan while passing, virtually ignored, by Western industry. By the time that their implications were understood, it was too late to save British consumer electronics; Japan had gained a foothold on the market.

Meanwhile Marconi Defence Systems is talking about improving its quality even more (for example, the company wishes to reduce still further the rate of PCB manufacturing errors, currently running at 24 parts per million). In addition, interesting new products are being developed – including the 'world's first real videophone'. Despite the negative views of industry pundits on such radical changes, Marconi Defence Systems have reinforced that old adage – you have to adapt to survive!

PICTURE CAPTION CHALLENGE

What a Tangled Web these engineers weave. This month we barely have our feet on terrestial ground. No prizes, but what is it all about?

★ Engineers preparing Wembley Stadium for the next Tina Turner concert.

★ More health and safety nonsense – compulsory absailing training for outside engineers, or how to get off a collapsing tower fast.

★ "I didn't realise installing Sky TV was going to be this complicated."

★ Putting the finishing touches to the most expensive Meccano set in the world.

Not quite. Actually, it is BT engineers clambering over their radio station at Dalton-in-Furness in the Lake District.

Events Listings

Till 29 May. DNA Fingerprints, Science Museum, London. (071) 938 8000. First of a series of exhibitions giving an insight into recent developments in science, technology and medicine.

Till 31 May. Catching The Action, MOMI, London. (071) 928 3232. A look at the early sequence photographers who paved the way for the coming of cinema.

9/11 June. Multimedia, Olympia, London. (081) 868 4466.

July 1992. Pop Video Experience, MOMI. (071) 928 3232.

20/24 July. Electro Tech '92, NEC, Birmingham.

Also watch out for:

22/24 September. Image Processing Exhibition, Birmingham. (081) 868 4466.

20 October/1 November. British International Motor Show, NEC, Birmingham. (0483) 222888.

Please send details of events for the Diary Listings to The Diary Editor, 'Electronics'.

ELECTRONICS IN AVIATION

Part Five Instrumentation

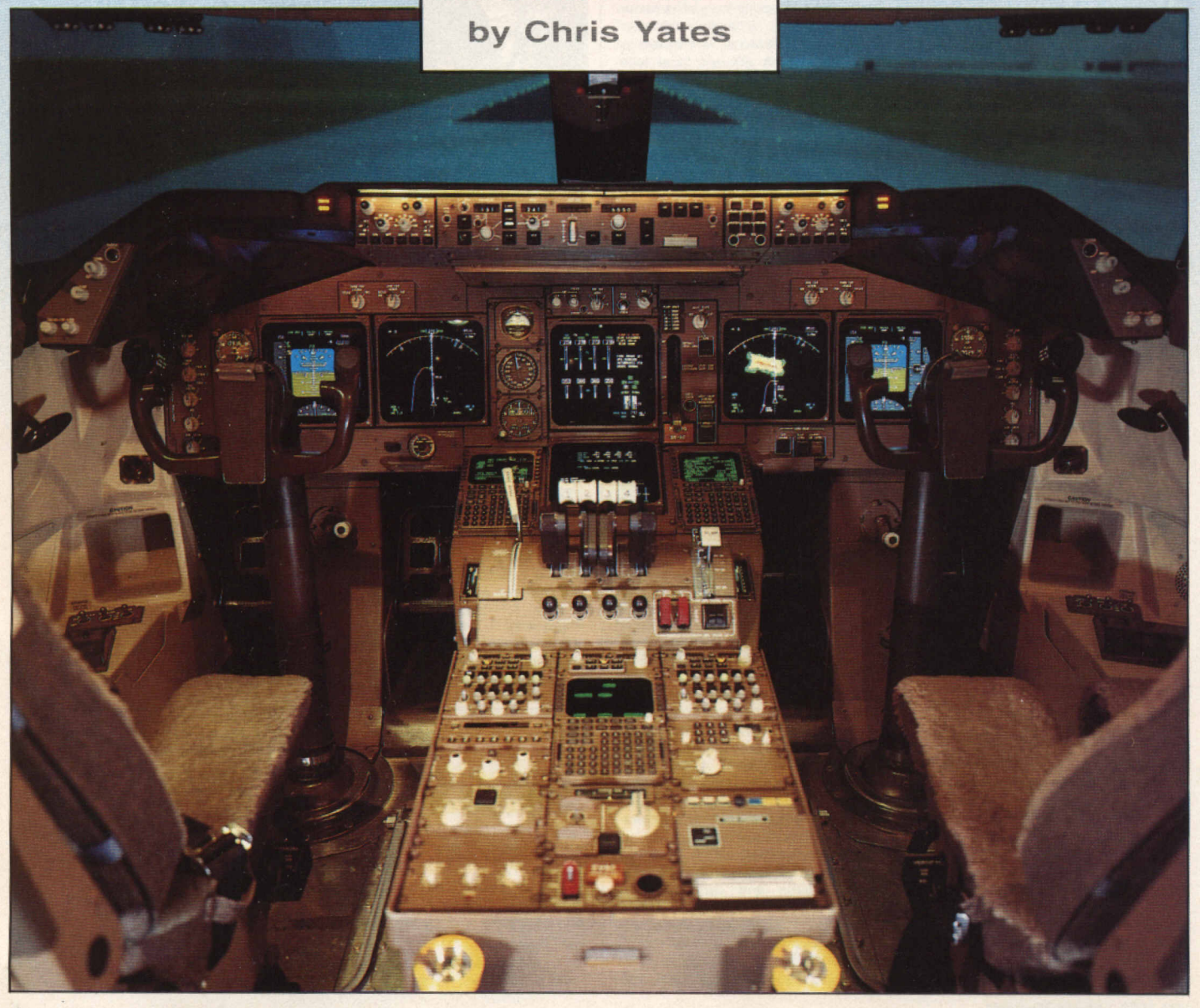
by Chris Yates

Whilst post-war developments were concerned primarily with ground-based electronic aids such as radar, radio communication and navigation systems, in recent years it is the flight-deck that has taken a technological leap forward. Nowhere is this more apparent than on board aircraft like the new Boeing 747-400 series intercontinental jets, where the myriad of electro-mechanical instruments that once monitored performance have given way to computer-aided electronic systems with their LED, LCD and CRT displays.

This high tech approach to avionics has not only improved system reliability, but has also eased fault diagnosis and made it possible for ground-based engineers to 'interrogate' aircraft systems in flight. It is a giant step forward that has also resulted in a considerable reduction in flight-deck workload, to the extent that even on the longest routes there is no need to carry a flight engineer.

The Hardware

Central to modern cockpit design is the Electronic Flight Instruments System (EFIS), comprised of four



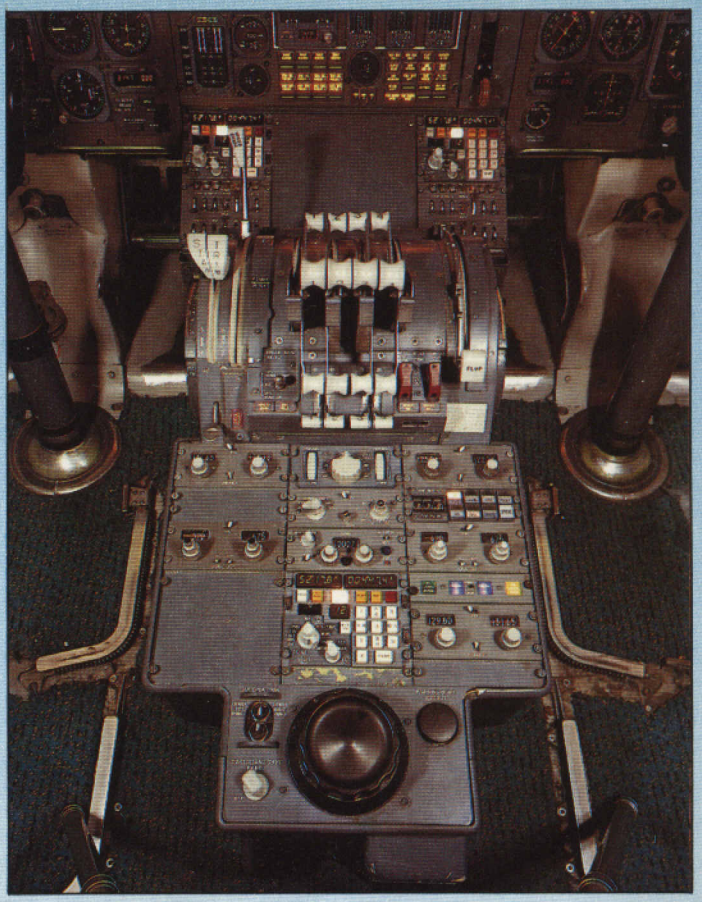


Photo 1 (left). Wide-angle view of the 747-400 series cockpit instrumentation, clearly showing how the EFIS system is arranged.
Photo 2 (top left). Close-up of the primary flight, navigation and EICAS displays. The MCDUs are clearly seen right and left of the lower EICAS display, and between the pilot's and co-pilot's radio controls.
Photo 3 (top right). Close-up view of 747-200 flight-deck. Compare this with Photo 2.
Photo 4 (above). The Flight Engineer's panel, no longer required with the advent of the 747-400 series aircraft.

CRT displays, which offers both pilot and co-pilot primary flight and navigation display information. The Primary Flight Display (PFD) – directly ahead of the control column – replaces the electromechanical Attitude Director Indicator (ADI) and also provides continuous readout of such parameters as altitude, airspeed, compass heading and so on.

Adjacent is the Navigation Display (ND). Shown in 'arc' mode, the scale represents the upper part of a compass rose and is further supplemented by a numerical readout of heading with respect to magnetic north. The ND also provides status information on available navigation aids, flight plan mapping facility, distance-to-go readout and a superimposed weather radar display.

An integral part of the EFIS package is the Engine Indication and Crew Alerting System (EICAS). This has revolutionised the 747-400 series flight-deck with its ability to suppress the least important information until it is needed, and has completely eliminated the requirement for an engineering control panel. EICAS automatically monitors the vital power-plant systems that were once watched over by a flight engineer; the crew are given an indication of such parameters as fuel status, turbine gas temperature, fan and core speeds, via two centrally located CRT screens. This provides a visual and audible early warning should a problem occur. All display functions are colour-coded to avoid confusion and to aid their readability.

With all the information at glass surface level, mis-readings due to parallax are no longer a problem.

Interface and Control

The data shown on the CRT is obtained from a variety of sources, including the flight guidance computers, navaids, radio altimeter and weather radar. It is selected via a device called the Multi-purpose Control and Display Unit (MCDU), via Electronic Interface Units (EIUs). Three of these MCDUs are installed as standard flight-deck equipment, receiving and disseminating their data via the Central Management Computer (CMC) and Aircraft Condition Monitoring System (ACMS).

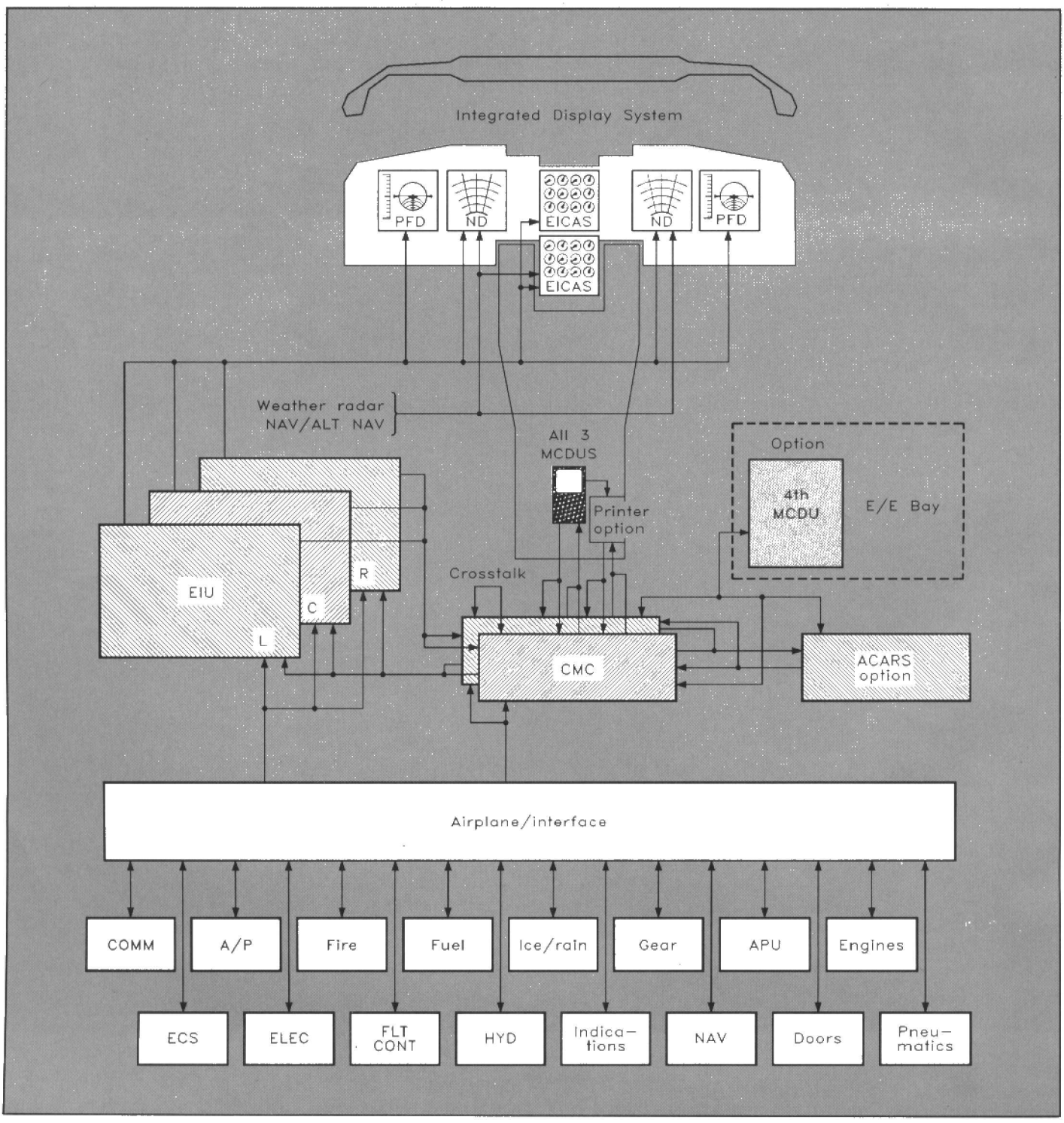


Figure 1. CMS, installed on the Boeing 747-400 series aircraft.

These MCDUs represent the 'human interface' for the 747's highly automated systems, providing the crew with a direct input capability to the very heart of the aircraft. In addition they can be used for such chores as the compilation and storage of flight plans – complete with waypoints and navigation beacons – and offer a useful data-link with 'home base'.

CMC and ACMS

The CMC is the aircraft's 'brain'. Deriving information from Built-in Test Equipment (BITE) and EICAS, fault conditions are diagnosed through a comparison of received data and internal tests.

In contrast, ACMS continually checks the 747's in-flight technical performance for tolerance abnormalities. Should ACMS detect a system operating outside its normal limit, it will store all relevant data prior to, and during the event, for further analysis. The overall system is shown, in diagrammatic form, in Figure 1.

Datalink

A unique feature of 747-400s, operated by companies like KLM Royal Dutch Airlines, is a 'Datalink' communications facility that can be used to automatically download information from CMC and ACMS to home base whilst the aircraft is still in flight.

Technical Specification Comparison

	Boeing 747-206B	Boeing 747-406
Length	70·51m	70·67m
Height	19·33m	19·33m
Wingspan	59·64m	64·83m
Engines	4 × Pratt & Whitney JT9D-7AW	4 × General Electric CF6-80C2
Max. thrust per engine	21,620kg	25,700kg
Fuel capacity	193,000 litres	212,000 litres
Fuel consumption	13,900 litres/hour	12,300 litres/hour
Weight (empty)	170,600kg	179,000kg
Max. payload	54,300kg	66,300kg
Max. take-off weight	351,530kg	394,600kg
Max. cruise speed	990km/h	1,020km/h
Norm. cruise speed	900km/h	910km/h
Range with max. payload	7,870km	10,800km
Capacity	387 passengers plus 20,300kg of cargo	425 passengers plus 19,000kg of cargo
Cockpit crew	3	2

The data is first transmitted to a VHF telecommunications station, and dependent upon where in the world the aircraft happens to be, it is transferred to an Aeronautical Radio Incorporated (ARINC), Air Canada, SITA (Société Internationale du Télécommunication) or AIRCOM (Air/Ground Communication) digital network. The ARINC network, and that operated by Air Canada, use a system known as the Aircraft Communications Addressing and Reporting System (ACARS).

Once at the nerve centre of the organisation concerned, the messages are despatched to airline headquarters (in the case of KLM, this is at Schiphol near Amsterdam) via the existing telex system. Here, messages are read by the central computer's 'post-office' function, which also notes which ground stations and organisation were used, before dis-

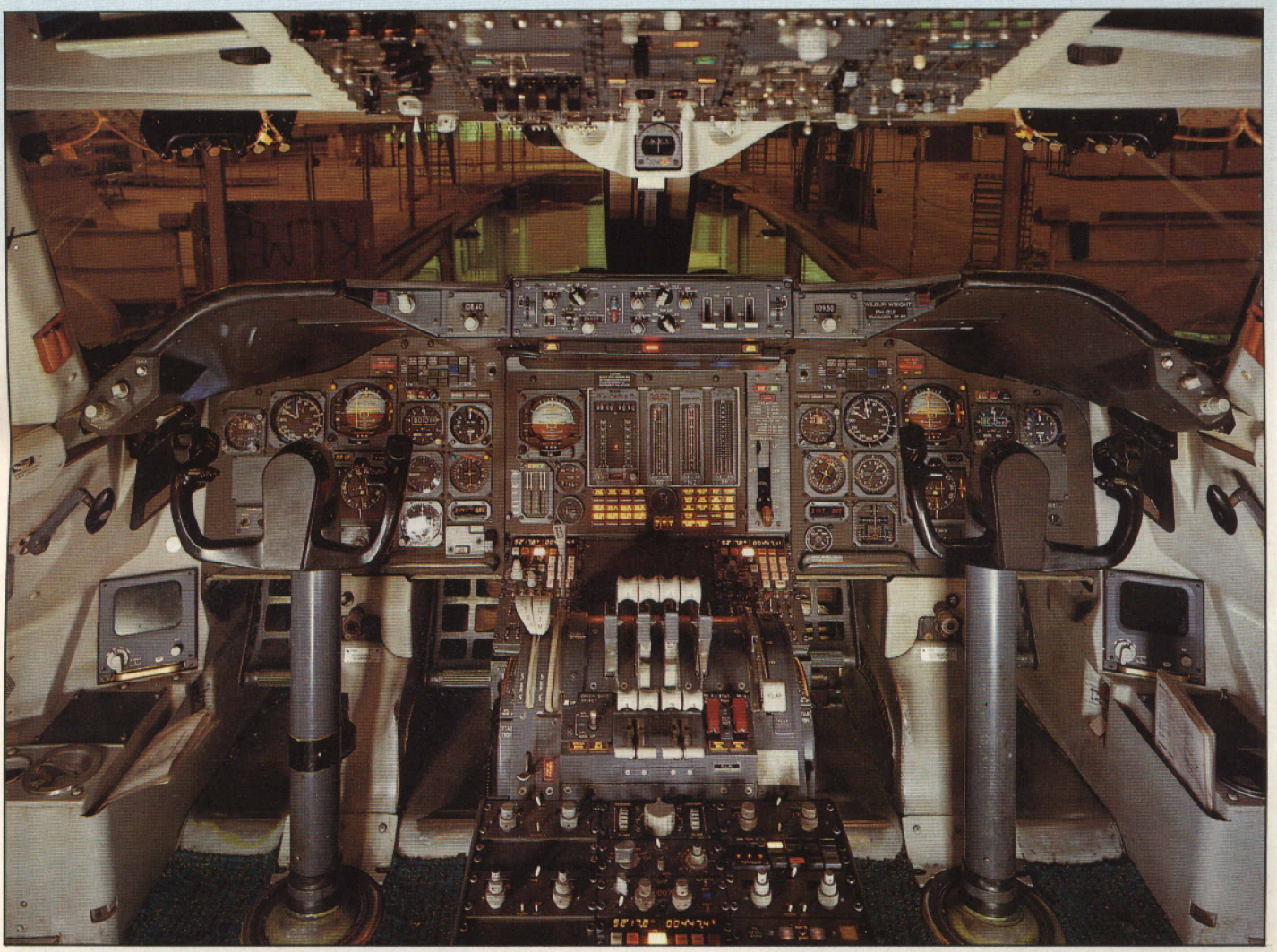


Photo 5. Wide-angle view of the 747-200 flight-deck. Compare and contrast this with the arrangement shown in Figure 1.

tributing them to the various end-users. In much the same way, requests for additional information from the CMC and ACMS can be made without the need for crew involvement. Not only does Datalink provide an automated information transfer between air and ground, but the crew can initiate communication by keying text into the flight-deck MCDU. Should the need arise, print-outs are also available.

This level of data transfer demands considerable communications processing. The 747-400 series aircraft are equipped with a Management Unit (MU) that can arrange, incorporate and compile received data into message format. These are combined with a time reference and address before being stored, awaiting onward transmission should a suitable ground station not be available. The MU also monitors uplinks, but only those with the correct aircraft registration and flight number are processed further.

Datalink is currently restricted to use in the USA, Canada, Europe, Australia and the Southern part of Asia – there being few suitable ground telecommunication stations elsewhere. However, advances in satellite technology could soon make instantaneous contacts possible irrespective of the aircraft's geographical position.

In Use

Whilst cockpit automation has resulted in increased avionics reliability and a greater degree of information available to the flight crew, it has also benefited the speedy turn-round and despatch of hard-working aircraft. For example, KLM combine CMC and ACMS reports with data culled from aircraft and cabin maintenance logbooks, HF/VHF radio messages, and the Technical Defects Information System (TEDIS).

In basic form, TEDIS utilises the public telex facility to link line stations (such as KLM operations at JFK airport in New York) with the Maintenance Support Facility (MSF), and enables engineers on both sides of the Atlantic to keep a constant check on the aircraft's technical status.

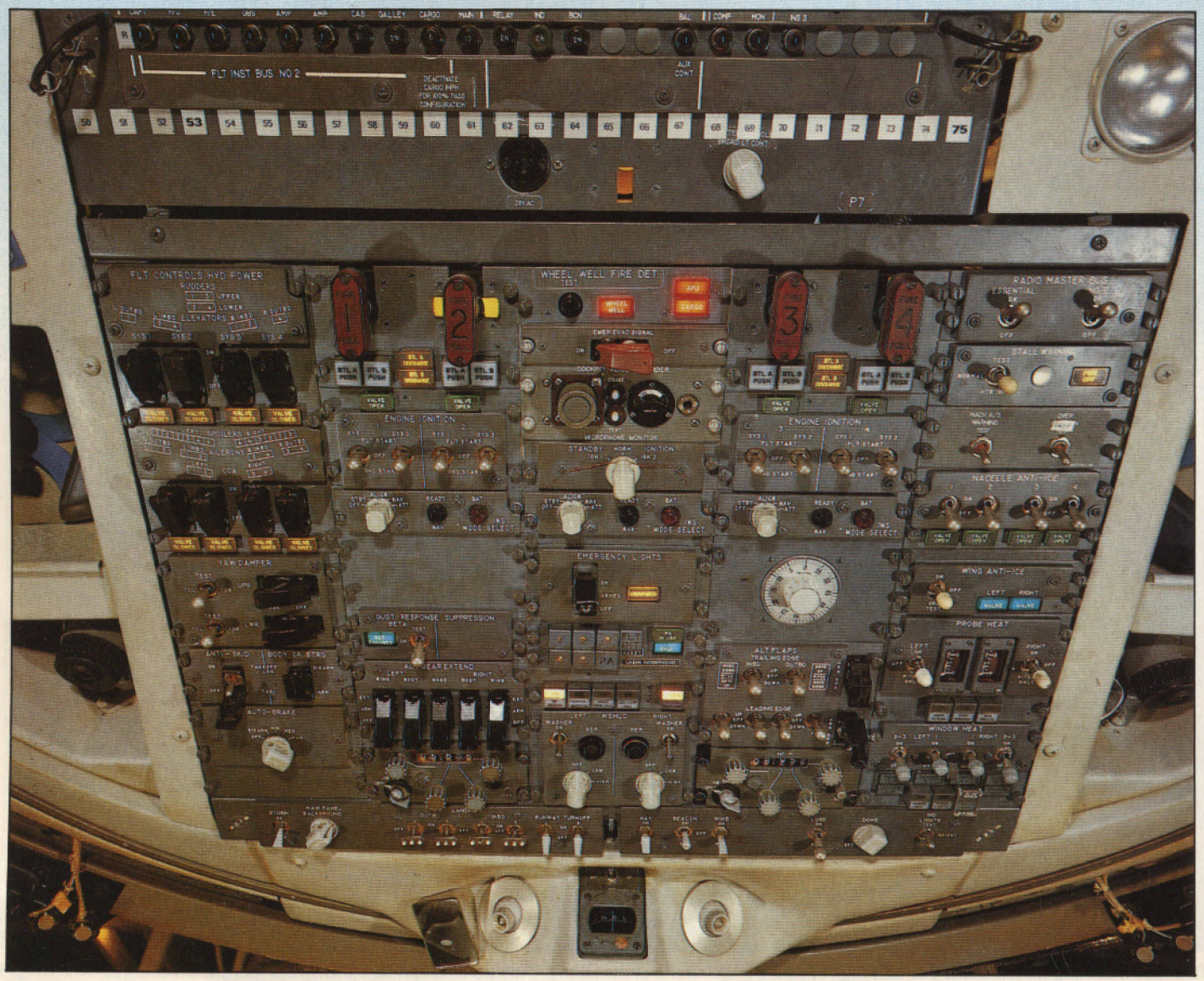
In addition to the other information above, TEDIS data is automatically or manually entered into the MSF, which combines the data from the various sources to produce a technical support form, enabling ground crew to have the necessary equipment and manpower available for repairs upon aircraft arrival. However, the story doesn't end there! As MSF is the maintenance 'brain' for the entire KLM fleet, it follows that the system not only receives information but sends it as well.

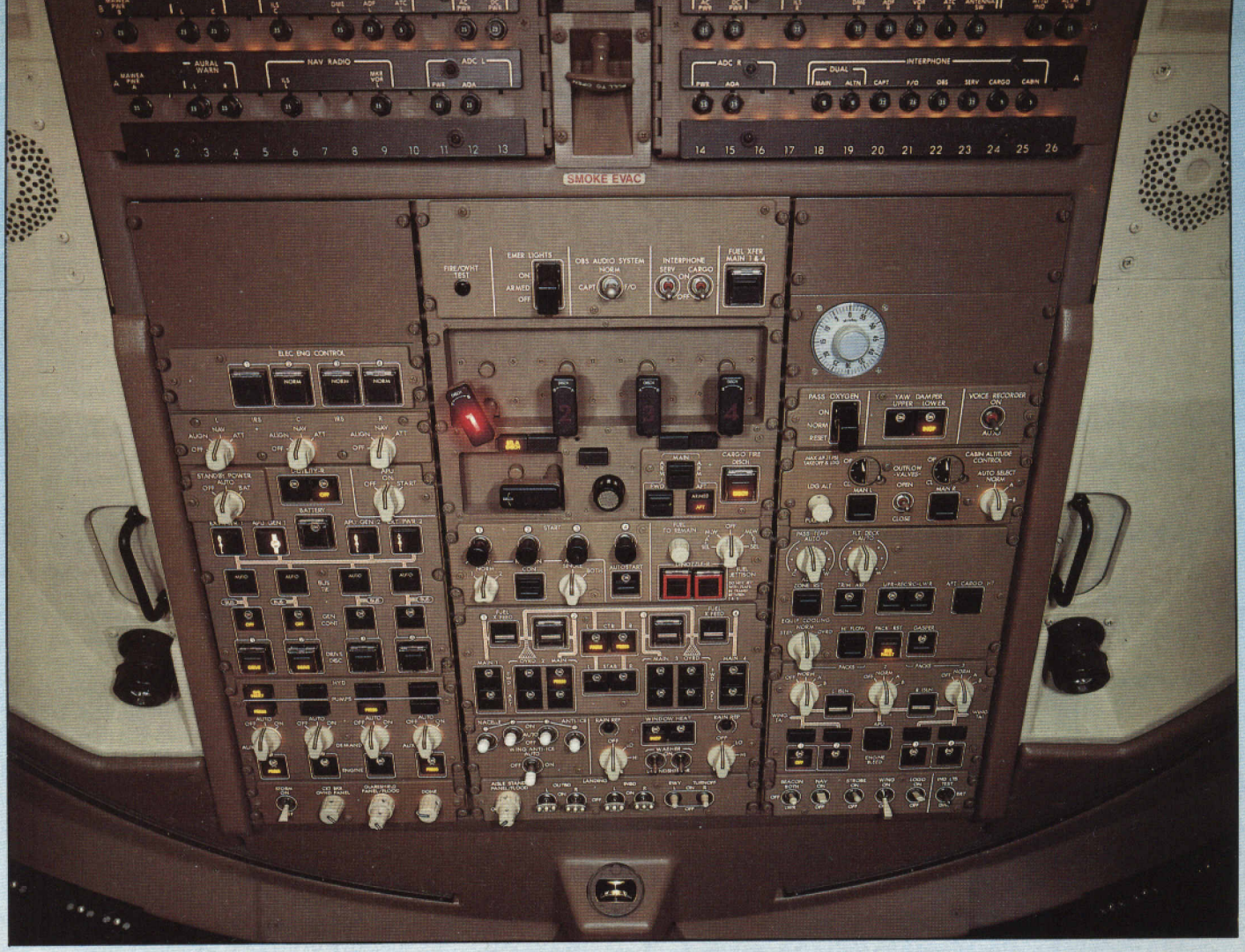
An example is the close relationship between MSF and the Computerised Rotable Control System (CROCOS). This interface enables the exchange of data about replacement parts, and whenever there is a shortage of spare parts CROCOS informs a maintenance department's material management team what to buy. EFIS, EICAS, CMC, ACMS, Datalink, MSF and CROCOS are all systems involving leading-edge technology. Together, they represent a state-of-the-art chain of command that is making the ultra-safe world of aviation even safer still – good news for the millions of people who travel by air every year.

Photo 6 (below). Overhead controls of the Boeing 747-200 series jet, shown for comparison with Photo 7.
Photo 7 (right). Overhead controls of the Boeing 747-400 series jet.

Acknowledgements

Acknowledgements are due to Cobie CH M Vink of KLM Royal Dutch Airlines, for the supply of photographs and helpful information.





747 Facts

The first Boeing 747 flew in 1968 and had a range of 7,200km. Twenty-four years later that range has increased to 12,200km.

Engine thrust has increased from 21,300kg per engine in the early versions, to 25,700kgs in the latest 747-400 series.

The difference between maximum take-off weight of the earliest 747 variant and the 747-400 series is 63,500kg – the total take-off weight of a 737-400 series jet.

More that 217km of wiring are needed for every new 747, and the instrument and control count has been reduced to 365 (from 971) by the advent of modern avionics technology.

The 747-400 series 'glass cockpit' (i.e. CRT) configuration is a hybrid version of the earlier electronic cockpits of the 757 and 767 aircraft, first seen in the mid-80s. These first-generation systems took some 10 years to develop and certificate.

The 747-400 series aircraft uses around 25% less fuel than its predecessor, and since the first scheduled service in January 1970 this family of aircraft has carried around 850 million passengers more than 20 billion kilometres.

It's a fact that Orville and Wilbur Wright could have completed their first flight in the 747-400's 45 metre long Economy Class Compartment!

Terminology

Term	Meaning
EFIS	Electronic Flight Instruments System.
EICAS	Engine Indication and Crew Alerting System.
CMC	Central Management Computer.
ACMS	Aircraft Condition Monitoring System.
MU	Management Unit.
MCDU	Multi-purpose Control and Display Unit.
EIU	Electronic Interface Unit.
ADI	Attitude Director Indicator.
PFD	Primary Flight Display.
CMS	Central Maintenance System.
CROCOS	Computerised ROtable COntrol System. The parts of aircraft registered on this system are coded. The CROCOS system maintains a list of these codes, noting when important components need to be replaced (the system is fed with flight data and maintenance records).
Datalink	A means of transferring digital information from aircraft to ground and back.
ARINC	Aeronautical Radio INCorporated, an aircraft addressing and reporting organisation. Non-profit making, it is operated by long-haulage airlines (mostly American).
AIRCOM	AIR/ground COMmunications services (digital data). European counterpart of SITA's Asian-based system. Developed by SITA.
SITA	Société Internationale du Télécommunication. In addition to developing AIRCOM, this French organisation operates a similar system (under the name of SITA), based in Singapore, which serves Asia.
ACARS	Aircraft Communications Addressing and Reporting System.
TEDIS	TEchnical Defects Information System.
HF	High Frequency.
VHF	Very High Frequency.
MSF	Maintenance Support Facility.
BITE	Built-In Test Equipment.

Design and Application of SEQUENTIAL LOGIC

PART SIX

by Graham Dixey
C.Eng.,M.I.E.E.

A register is essentially a digital device for storing binary data. This it is able to do since it consists of a string of flip-flops, which are bistable devices. As such, each is able to take up one of two states: either its Q output is at logic 0 (in which case it is said to be storing a logic 0), or it is at logic 1, when of course it is storing a logic 1 instead. If the register is able to store data, then provision must be made for inputting that data and, of course, for retrieving it some time later. This leads to four main methods of input and output combinations. Because the flip-flops are connected in sequence, they may be seen as being essentially in series. This leads to the idea that data may be 'serially shifted' through the register which, in turn, gives rise to the possibility that this shifting may be carried out in either direction. It is the application of the above ideas to practical circuits that we are concerned with in this part of the series.

Data Input and Output

There are just two ways in which data may be shifted from point to point – either serially or in parallel. In the serial method of transmission the data bits are sent one at a time; only a single line of communication is needed which makes it simple from the wiring or circuit point of view, but it is relatively slow. In the case of parallel data transmission, each bit has its own line and so all bits can be transmitted at once. The wiring is more complex but the speed is much higher.

Although the above argument seems to apply to data transmission over a distance, it is equally valid when considering how to load data into a register and how to retrieve it. Figure 1 shows the four combinations of serial and parallel loading/retrieval methods mentioned earlier. A register is shown simply as a rectangle which could represent a register of any required length.

In the example shown in Figure(a) the data is presented serially at the left and output serially at the right. Under the action of a clock pulse, data is 'shifted' through the register from left to right; one clock pulse shifts the entire contents of the register one place to the right, the rightmost bit leaving the register and a new bit of data entering at the leftmost position. Such a register is termed Serial In-Serial Out (SISO). The number of clock pulses required to shift a complete word in and then out of the register depends upon the number of bits that the register can hold.

Suppose that the register is 8-bit and is initially 'empty'. If an 8-bit data word is presented at the input, it will require eight clock pulses before the first bit to come in has reached the rightmost place; by this time all eight bits of the data will have been stored in the register. In order to shift this word out, a further eight clock pulses will obviously be required, making a total of 16 clock pulses altogether. In fact, for any register of this type with a capacity of 'n bits', the number of clock pulses to shift a complete word in and then out again will always be equal to 2n pulses.

To go now to the other extreme, Figure 1(b) shows a Parallel In-Parallel Out (PIPO) type of register. In this type of register – although it is not clear from this particular diagram – there is no direct connection between the flip-flops (apart from the clock and reset lines), and each is essentially a single-bit store just for that line to which it is connected. Data in the form of an n-bit word is presented to all input lines simultaneously. On the application of a single clock pulse each bit of that data is loaded into its appropriate flip-flop. The entire data word is thus immediately available at the n-bit output lines. Essentially the action of the clock pulse has been to effect a transfer of data from input to output, replacing the data that was previously at the outputs. This can be seen as a method for updating data and is commonly used as an interface between binary counters and digital displays, as in clocks, voltmeters, etc.

Figure 1(c) shows how it is possible to convert data in serial form into a parallel format. The data word is presented serially at the input, as in Figure 1(a), and requires 'n' clock pulses to input the complete word. However, now that it has been stored, it is immediately available at the Q outputs as a parallel word; it is simply a matter of making the parallel connections.

Conversely, Figure 1(d) shows how to

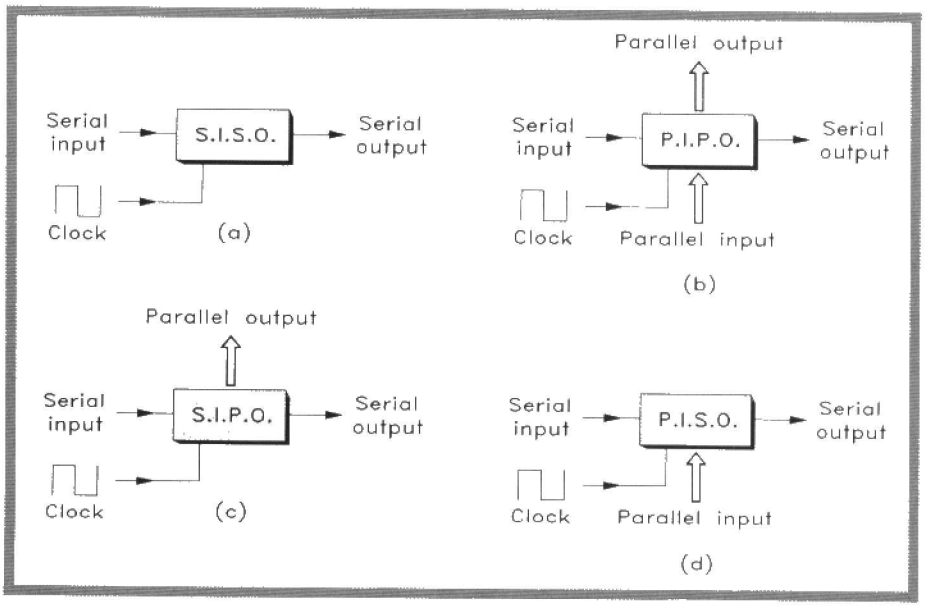


Figure 1. The four main methods for accessing a register for data input/output. (a) serial-in/serial-out (SISO); (b) parallel-in/parallel-out (PIPO); (c) serial-in/parallel-out (SIPO); and (d) parallel-in/serial-out.

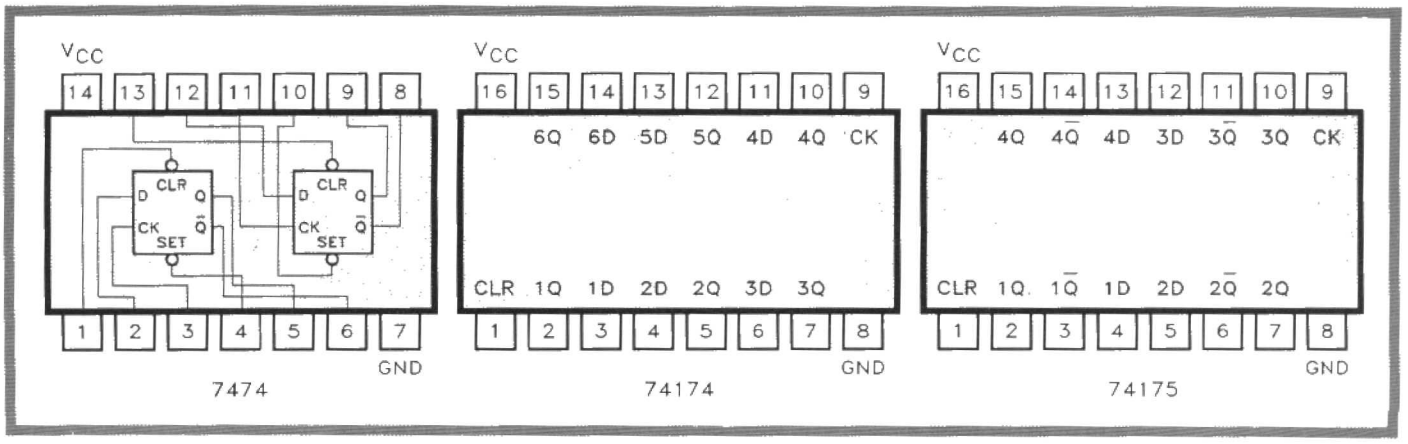


Figure 2. Pin-outs for some D-type flip-flop ICs.

convert from parallel form into serial data. The n-bit word is presented at the parallel inputs and is stored with a single clock pulse. It can then be serially shifted out, appearing one bit at a time at the serial output.

Methods (c) and (d) above illustrate the basic principle involved in allowing two parallel devices to 'talk' to each other over a serial line. The 'talker' converts the parallel data into serial form, which passes into the line while the 'listener' converts the incoming serial data back into parallel form.

The D Flip-Flop – The Basic Register Element

The type of flip-flop most commonly used in register applications is the D-type (D = Data). The pin-out for the 7474 IC, which contains two, independent D-type flip-flops, is shown in Figure 2, together with the pin-outs for the 74174 and 74175 hex and quad D-type latches. In this context, a D latch performs the same function as a D flip-flop (although there are also unclocked latches which cannot be used in the same way). It *is* possible however to press a JK flip-flop into service as a D-type, should one wish to do so, with a simple modification. This consists of connecting an inverter between the J and K inputs, so that the latter are always complementary. However, before we consider this improvisation any further, let us look at the operation of the D-type itself, as shown in Figure 3.

Apart from terminals for pre-setting and pre-clearing, this device has only a D (data) input, a clock input and the usual pair of complementary outputs, Q and $\overline{Q}$. The data bit to be stored is presented at the D input; upon the clock going high this bit is stored at Q by the action of Q assuming the same logic level as exists at D. This is described by the truth table in which Q after the clock pulse always equals the value of D, irrespective of Q's initial value. The preset and clear inputs are asynchronous, which simply means that they can be taken low to preset or clear the register at any time, quite independently of the clock.

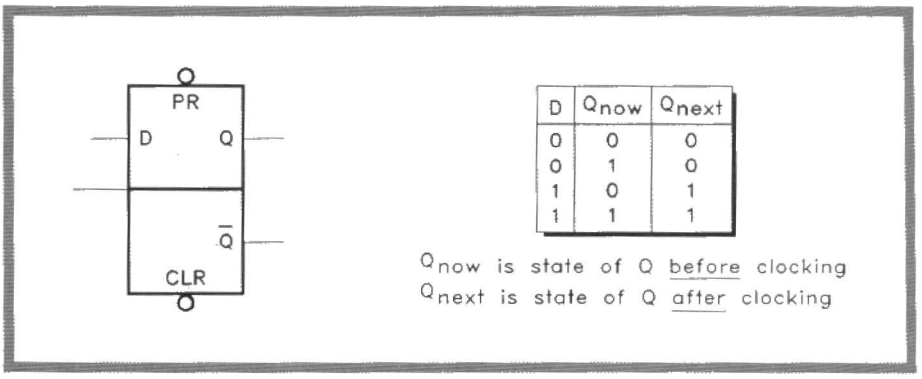


Figure 3. The D-type flip-flop, circuit symbol and truth table.

To return to the JK used as a D-type, this is shown in Figure 4 together with its truth table. The latter will be remembered from previous discussions about counters. The relevant lines are the second and third, since the first and last lines are impossible; the inputs must always be complementary. Consequently, the flip-flop is always in either the RESET mode (J = 0, K = 1) or the SET mode (J = 1, K = 0). Thus, clocking it will cause either of these operations as appropriate. If we consider that the J input acts as the D input of a D-type device, then its use as one of the latter group is clear. When J = 0 (i.e. D = 0), Q becomes 0 after clocking; when J = 1 (i.e. D = 1), Q becomes 1 after clocking.

The Basic Serial Register

First let us construct one of these from available D-type flip-flops. This is very simple if all we want to do is shift data serially from input to output. The serial input to the register is the D input of the first stage (stage A). The Q output from this stage connects to the D input of stage B, and all following stages are connected in a similar manner. The Q output of the last stage (stage D) is the serial output of the register. The clock line is common to all stages, as is the clear (reset) line. This circuit is shown in Figure 5(a), while its direct equivalent is included in Figure 5(b) for comparison. This is the last time we

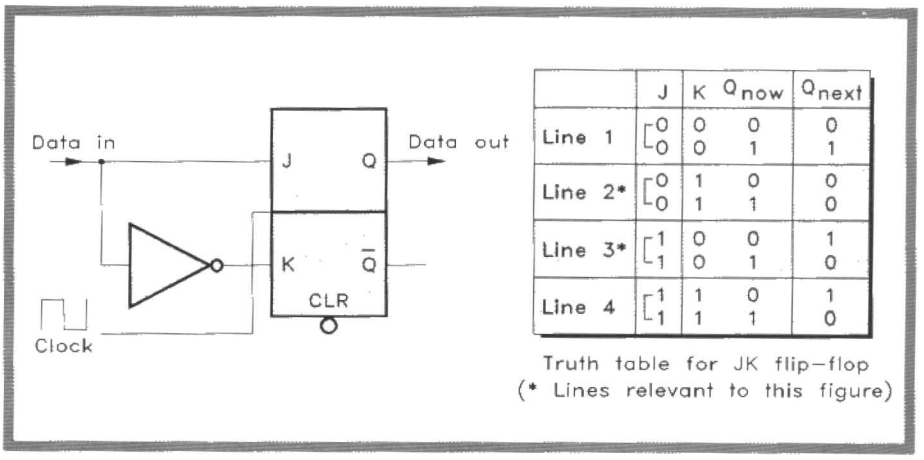

Data in
J
Q
Data out
K
Q̄
CLR
Clock
J | K | Qnow | Qnext
Line 1 | 0 0 | 0 0 | 0 1 | 0 1
Line 2* | 0 0 | 1 1 | 0 1 | 0 0
Line 3* | 1 1 | 0 0 | 0 1 | 1 0
Line 4 | 1 1 | 1 1 | 0 1 | 1 0
Truth table for JK flip-flop
(* Lines relevant to this figure)

Figure 4. The JK flip-flop adapted for use as a D-type.

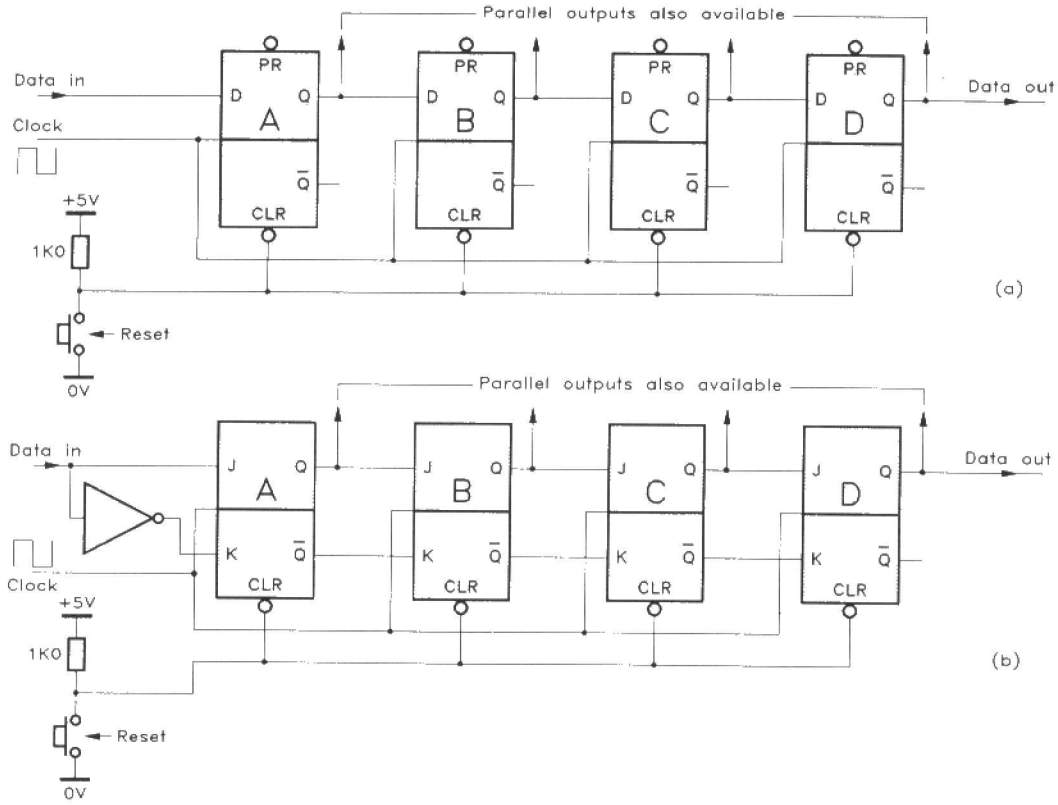


Figure 5. A 4-bit serial shift register (a) using D-type flip-flops, and (b) using JK flip-flops.

shall mention JK flip-flops in connection with registers.

Figure 5 also shows how simple it is to convert the SISO type of register to have a parallel output (SIPO) as an alternative. All that is needed is to make the Q outputs available. From a discrete point of view this is no complication at all, but from the IC manufacturer's viewpoint it would mean providing extra pins on the chip package.

Parallel Load Registers

Given that in order to load the register with parallel data some extra logic is required, it is then an easy matter to retrieve this data either by serial shifting or in parallel form at the Q outputs, both of these options being shown in Figure 6. The logic used to perform the load operation however, is interesting in itself.

The pre-clear and preset inputs to

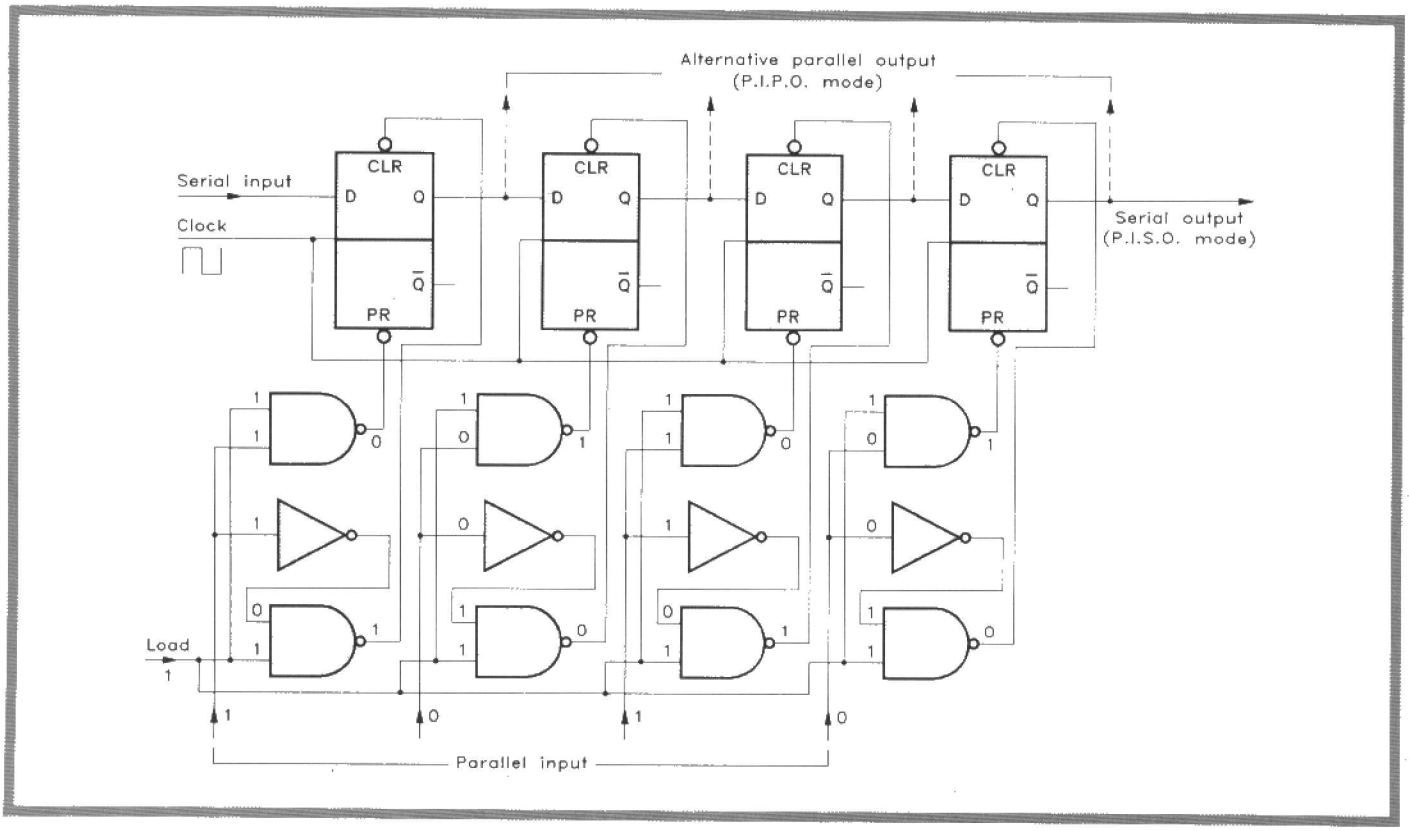


Figure 6. The parallel load register for either serial (PISO) or parallel (PIPO) output.

each flip-flop are used, these being driven in complementary fashion by the logical outputs from a pair of NAND gates. An inverter is used to obtain this complementary relationship. A LOAD line is connected to the alternate input of all NAND gates; this has to be taken high in order to perform the load. According to NAND logic, the output of a NAND gate will only go low when all of its inputs are at logic 1. To avoid a tiresome and confusing blow-by-blow explanation of this action, I have included the logic levels in Figure 6 instead, at all relevant points, showing the sample data and the LOAD line taken high. From this it can be seen that, whenever a logic 0 is to be loaded, the PRE-CLEAR pin is taken low and whenever a logic 1 is to be loaded the PRESET pin is taken low instead.

Parallel Load Shift Register Packages

There are a number of available packages which permit parallel loading of data and the options of serial or parallel output. Examples are shown in Table 1. This table also lists other attributes or restrictions on the use of various different types of registers.

For example, the 7495 (Figure 7(a)) is a 4-bit register that permits both left and right shifting of data, as well as having both parallel inputs and outputs. There are two modes, known as SHIFT and LOAD. To select SHIFT, the 'mode input' must be taken low. The data may then be shifted right by clocking the SRT (Shift RighT) pin, or left by clocking the SLT (Shift LefT) pin. To select LOAD, the 'mode input' is taken high and the data on the parallel inputs is then able to be entered into the register by taking the SLT pin low.

The 7496 (Figure 7(b)) affords an interesting comparison. For a start it has five stages. It only shifts right and, although it has both parallel load and parallel output facilities, there is a restriction on the former method that one must be aware of. The register must be *cleared* before loading new data. This is because it is impossible to overwrite a '1' in the register with a '0'. After clearing (CLR input briefly taken low) the loading is carried out by a low to high transition at the LOAD terminal. In order to shift the data, the CLR pin should be held high while the LOAD pin is held low; clock pulses on pin 1 will then shift data from left to right at the clock rate.

A Pair of 8-Bit Shift Registers

Figure 8 shows the 74164 and 74165 8-bit shift registers. These have somewhat different characteristics, as follows.

The 74164 shifts right only, and can be used as a SISO or SIPO type only. It has clock and clear inputs and also a pair of serial inputs. For normal serial shifting one of these is held high while the input data is applied to the other. If either of

Type	Length	Parallel load method	Shift direction	Clear
7495	4 bits	Synchronous	Right/left	No
7496	5 bits	Preset only	Right	Yes
74165*	8 bits	Asynchronous	Right	Yes
74166*	8 bits	Synchronous	Right	Yes
74194	4 bits	Synchronous	Right/left	Yes
74195	4 bits	Synchronous	Right	Yes

* Parallel output not available

Table 1. Summary of parallel load shift registers.

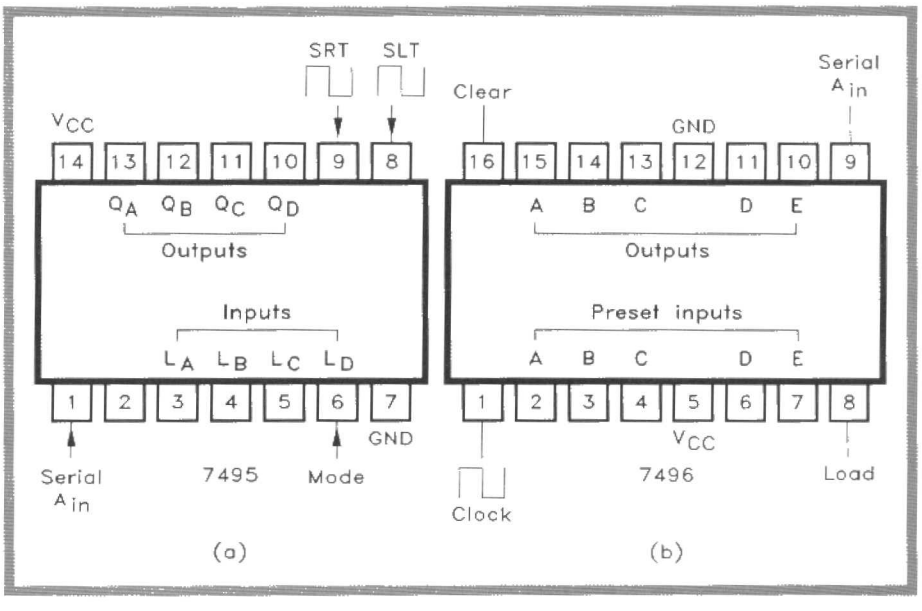


Figure 7(a), the 7495 4-bit shift register; (b), the 74165.

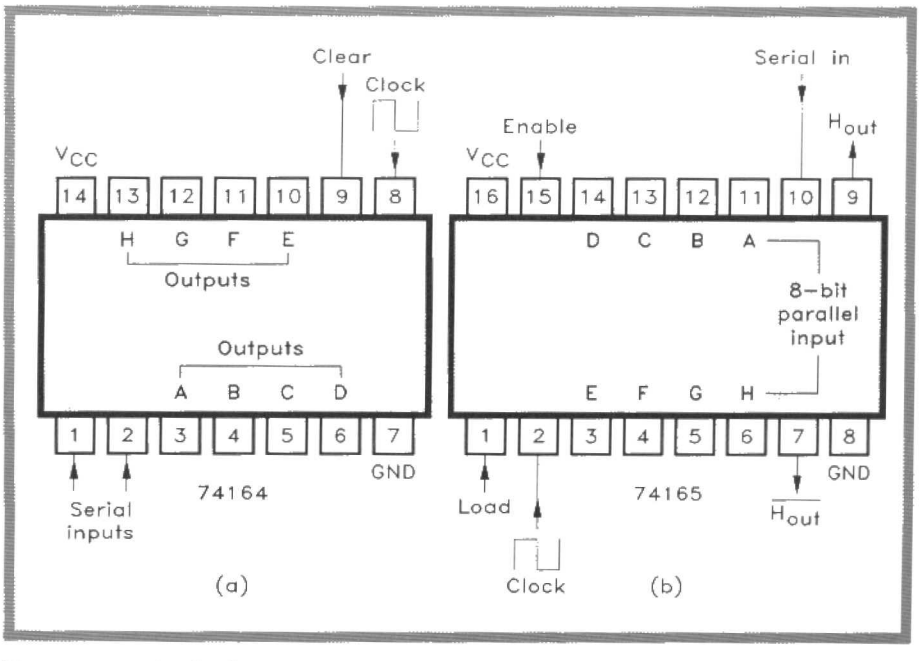


Figure 8. A pair of 8-bit shift registers: (a) the 74164, and (b) the 74165.

these serial inputs is held low, it forces the data input low, thus effectively inhibiting the input of data.

The 74165, by comparison, is a parallel-in/serial-out type and can be used for either SISO or PISO operation. It has an ENABLE pin which must be held low for normal operation, otherwise the operation is disabled. The LOAD pin must be held high, except during the loading of data when it should be brought low for the loading period. The restriction for loading data that exists in the 7496 is absent from this register.

Ring Counters and Twisted Ring Counters

These are examples of shift registers that employ overall feedback. Feedback is taken from the final Q output and redirected back to the first D input. It is necessary to put a '1' into the loop so formed, and provision must be made for this in the design. All that it involves is clearing the ring initially, and then pre-setting just one of the flip-flops, usually the first. Clocking the register causes the '1' bit to circulate continuously around the ring. What is happening is that the data – a single 1 plus n – 1 0s – is being right shifted from the leftmost to the rightmost position in the usual way, and then being re-entered into the leftmost flip-flop via the feedback path. A 10-stage ring counter design is shown in Figure 9.

This circuit comprises two separate flip-flops, plus the 8-bit 74164 shift register. It is necessary to have at least one independent D flip-flop, since this provides the means for injecting the '1' into the loop; it is not possible to preset an individual stage of the 74164 IC. The INITIALISE RING line is connected to the PRESET input of the first D flip-flop to the PRE-CLEAR input of the second one and to the CLEAR terminal of the 74164. The term 'initialise' is preferred here, since only nine of the stages are cleared, the other being preset in order to put the '1' into the ring. All stages are clocked simultaneously.

This circuit is sometimes referred to as a 'stepper', because the 1 state 'steps' from one position to the next at the clock rate. This is shown also in Figure 9 by the first few waveforms that would be observed at the terminals indicated. In this context it is a useful circuit for sequential selection, for example in multiplexing applications. However, the term 'counter' has been used in the title, and this can be justified by the fact that for each one of ten input pulses there is a unique state: 1000000000, 0100000000, 0010000000, etc. Thus, provided that it is possible to decode each state, this circuit can be regarded as a non-weighted decade counter. In this application it is very inefficient, because it requires so much hardware to perform a simple task – 10 stages plus decoding etc. This compares unfavourably with a conventional decade counter such as

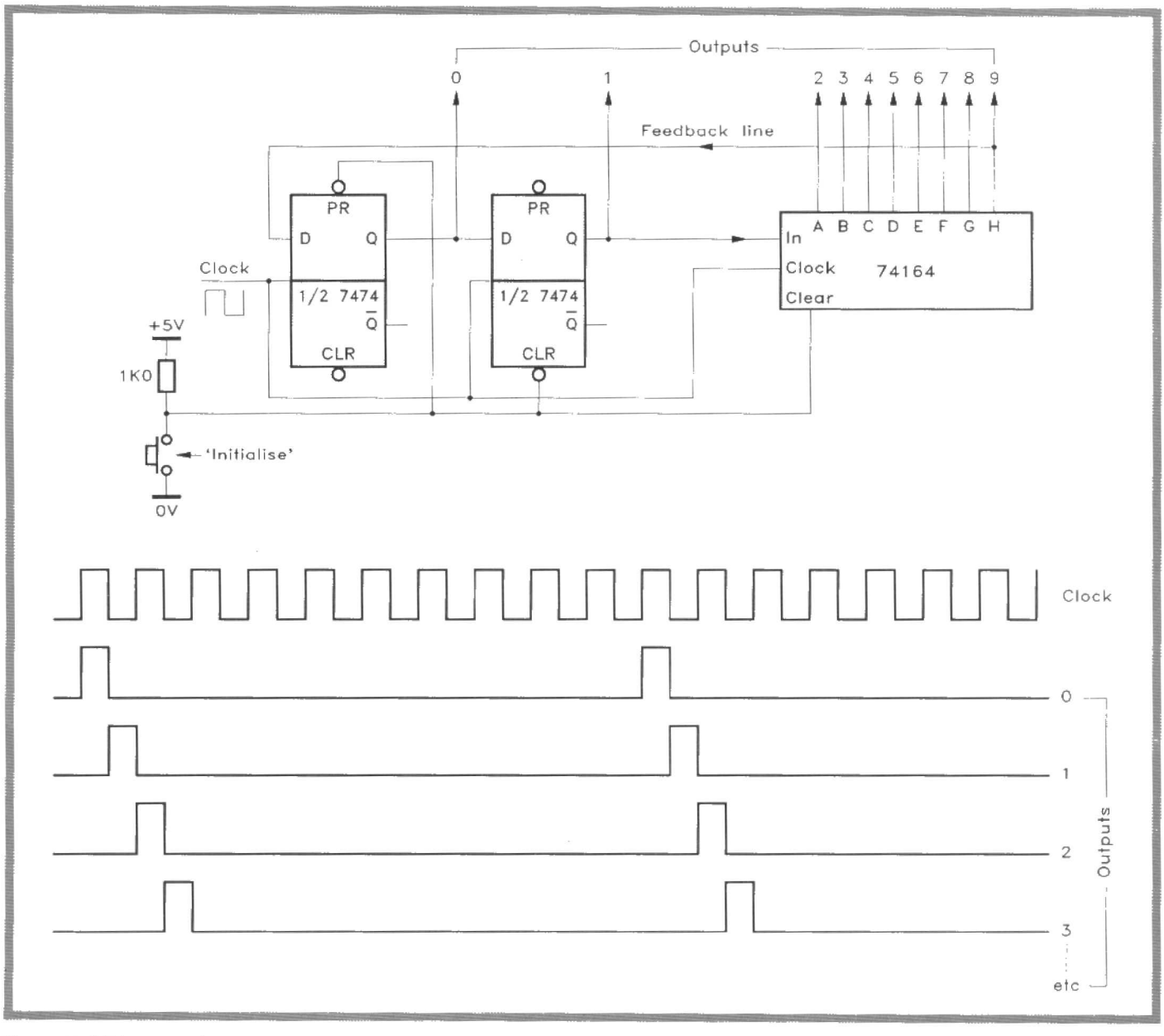


Figure 9. A 10-stage ring counter.

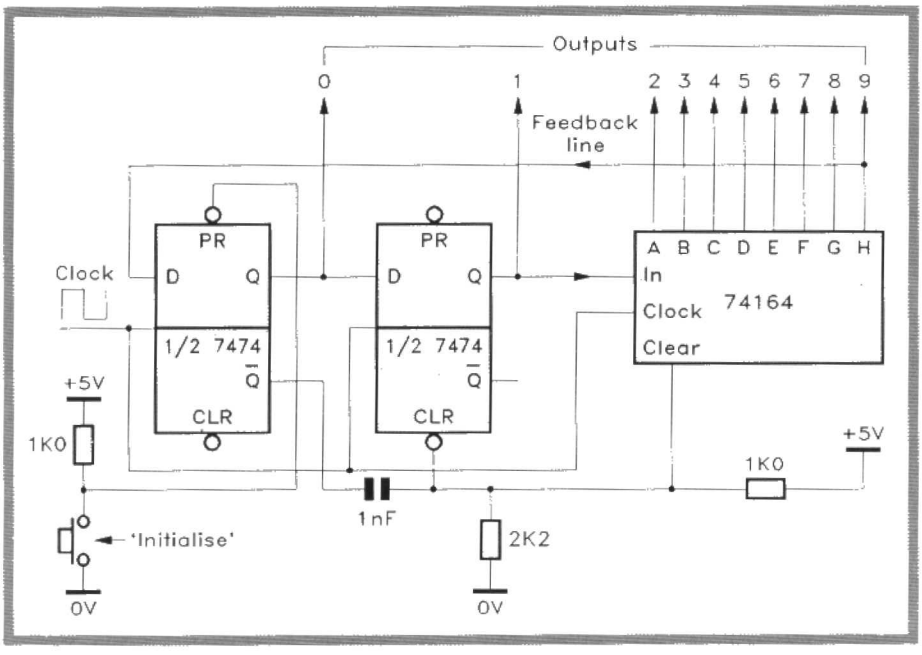


Figure 10. The circuit of Figure 9 modified to clear disallowed states automatically.

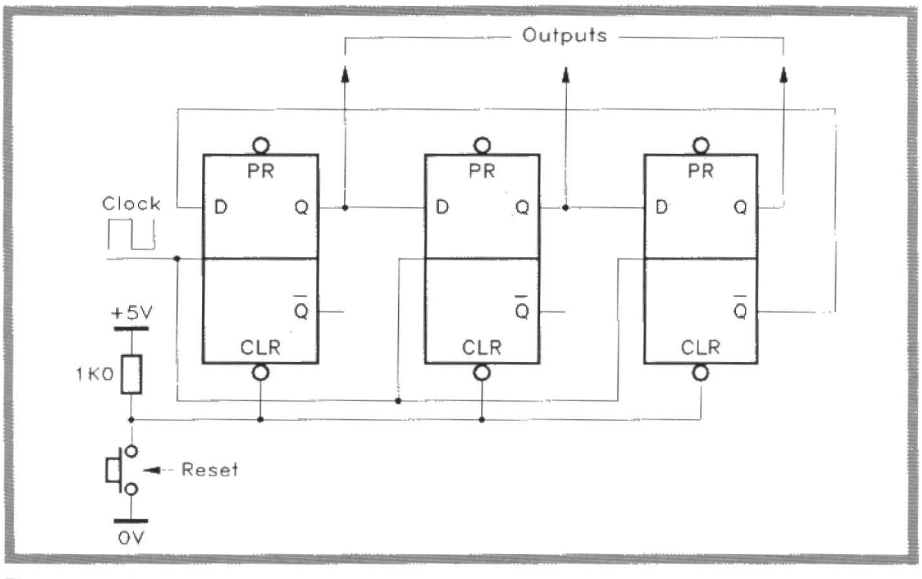


Figure 11. The twisted ring or Johnson counter.

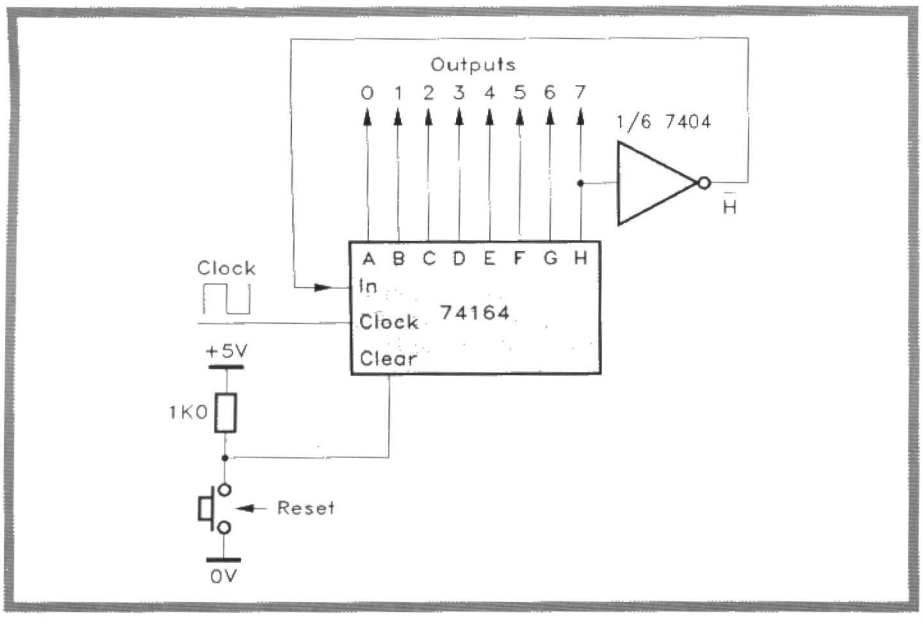


Figure 12. A 10-stage Johnson counter with a minimal chip count.

the 7490, which is a single chip device that does not need decoding. There is another problem as well.

A binary device with 10 stages can take up $2^{10} = 1024$ states. But in this design we are only using 10 of them – the ones with only a single 1 in them! What happens to the other 1014 possible states? These are known as 'disallowed' states and, in theory, the counter will never enter them. However, if it does somehow get into one because of the presence of noise, for example, it will never get out again by itself. For instance, if a second flip-flop gets accidentally set to 1, such that we get 1000100000, then the sequence will go 0100010000, 0010001000, etc. There are now two 1s in permanent circulation around the loop. With so many disallowed states in existence, the chances of getting into one of them are obviously high. Figure 10 shows how we can make the circuit clear any disallowed states automatically by clearing stages 2 – 10 every time the circulating 1 reaches the first stage.

Did I say the circuit would clear ANY disallowed states? Almost true, but there are TWO that it won't clear. Can you deduce which ones they are? I'll give the answer next month.

It is also possible to take the feedback from the $\overline{Q}$ output of the final stage instead of Q. See Figure 11. In this case we don't need to preset any of the stages to initialise the circuit, merely clear them all. When we do this and then start clocking the circuit, a 1 will be fed into the first stage via the feedback from the Q output of the last. This 1 exists because all stages (including the last) have been cleared, which means that the $\overline{Q}$ output of the final stage must be at logic 1. It will remain at this level until this stage is itself set by the '1s' that, in synchronism with the clock pulses, progressively fill the register from left to right; then the logic level on the feedback line will fall to logic 0. This will now cause the register to fill with 0s. The level on the feedback path will switch to logic 1 once more, and the sequence will repeat.

This counter is known as a 'twisted ring' or Johnson counter, and it has twice the number of states of the ring counter for a given number of stages. A 10 stage counter would then have 20 states. In the case of the simple three stage Johnson counter shown here, there are six states which are: 000; 100; 110; 111; 011; 001.

As can be seen, in order to function, the $\overline{Q}$ output of the final stage needs to be available. If we want to use a 74164 to form an 8-stage Johnson counter we shall have to generate Q by using an inverter, as seen in Figure 12. This gives us a design that only uses two ICs: one 74164 and one 7404. Had we built up the same circuit using dual-D type chips (7474), we should have needed four of them.

The next article is the final one in this series. It will deal with the problems and techniques of interfacing counters and registers to external devices.

EnviroSynth

by Ian Hickman

Photograph shows author's Prototype. Please note: Case/Knobs shown, are not included in the Kit, and are not available from Maplin.

FEATURES

- ★ Simulates a gentle breeze, or surf on the shore, as well as providing pink and white noise outputs
- ★ Sounds can be tailored to user's requirements

APPLICATIONS

- ★ Aids relaxation, insomnia and coping with stress
- ★ Sound effects for theatres, radio shows and video/film productions

This article describes the design and construction of a versatile noise generator. All you (environmentally) green constructors may be wondering at this moment why anyone should want a generator of 'acoustic pollution'. But there is noise – and *noise*. The EnviroSynth offers a choice of white noise, pink noise, breeze in the trees or surf on the shore. The latter two sounds are, in fact, extremely soothing – and can be very useful in cases of insomnia caused by tinitus, worry, overtiredness, or so on. The 'surf' sound in particular is designed to be non-threatening, having been tailored to sound like the breaking of rollers on a pebble beach, heard through an open window in a house at a little distance from the shore. To help with sleep, place the unit near your bedroom window. The 'breeze' noise can be tailored at will during the construction stage, to sound like anything from the screaming of the tempest over the ruins of Dracula's castle, through the bracing whistle of the wind around a climber belayed on a rock face, to the gentle sighing of the summer airs in the sun-dappled woodland; the latter

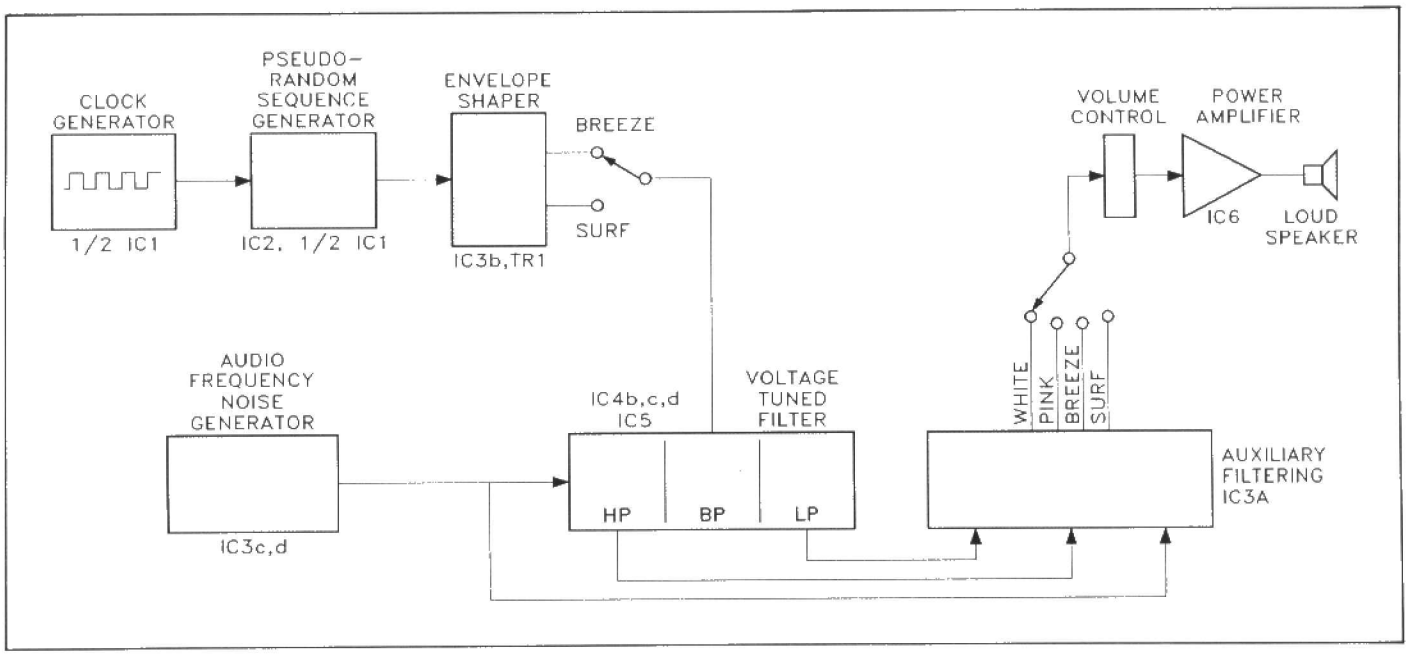


Figure 1. Circuit block diagram.

effect is recommended for insomniacs. Both breeze and surf are also very useful in doctors' (and more particularly dentists') waiting rooms.

Even white noise has its uses. Sounding as it does like escaping steam, it is completely unvarying and featureless, and can be used, at a suitably low level, to simulate the slight background noise commonly found in air-conditioned offices. People usually prefer this to the dead silence often experienced in a quiet carpeted office area; it is also useful in reception areas for preventing confidential telephone conversations in adjacent offices from being overheard. White noise has constant power per unit bandwidth, e.g. the same amount of power in the band 500 to 1000Hz as in 1000 to 1500Hz, 1500 to 2000Hz, etc. Pink noise is somewhat similar to white noise, except that its power spectrum has a 3dB per octave roll-off with increasing frequency. In other words, it has constant power per octave, rather than per unit bandwidth. This gives it a distinctly 'mellower' sound and consequently, it can be used as background noise at a somewhat higher level.

Circuit Description

The unit consists of a number of easily identifiable functional blocks, which are shown in Figure 1. Two Op-amps are used to generate broadband audio-frequency noise and this, after level-setting and simple filtering in the auxiliary filtering section, provides the unvarying white or pink noise output. Clock generator IC1 produces a low-frequency clock waveform, which drives a maximal length pseudo-random sequence generator. This produces sub-audio frequency noise, with a white frequency distribution, which is modified in the envelope shaper section to produce appropriate envelope waveforms to control the voltage variable filter, which is comprised of IC4 and IC5. The high-pass and low-pass outputs of this SVF (state variable filter) provide the surf and breeze outputs respectively. After some further auxiliary filtering, these are also available, along with white and pink noise, at the selector switch for passing to the volume control, power amplifier and loudspeaker.

Op-amp IC3d is set to provide a gain of 50dB (or x300) by R16 and R17, see Figure 2. Its output is therefore an amplified version of its own input noise. This is coupled via C7 to IC3c, another Op-amp section providing 48dB of gain. Below the $1/f$ corner frequency, the noise output can be expected to rise, but this is compensated by C7 and R19, and by any limitations of the loudspeaker and cabinet used. This flat, high-level noise is attenuated by level-setting attenuator R22 and R40, and forms the white noise output, which is fed to the volume control and output amplifier via S1c and C17. In the pink noise position of selector switch S1, R22 provides a 6dB per octave roll-off starting at 800Hz. This, in conjunction with the generally rising response of the loudspeaker, provides an approximation to the true 3dB/octave roll-off of pink noise.

For the 'breeze' and 'surf' sounds, the white noise is passed to the SVF formed by IC4, IC5 and associated components. The high-pass output, at pin 14 of IC4d, provides the 'surf' signal, whilst the output of the low-pass filter, at pin 7 of IC4b, furnishes the breeze output. The filter is operated at a Q of $\frac{1}{3}$ in the 'surf' mode, and a Q of just under 2 in the 'breeze' mode, as determined by R38, R25 and S1b. Whilst the Q is fixed at one or other of these values, the cut-off frequency of the filter varies with time. This is due to the varying bias drive to the two OTAs (operational transconductance amplifiers) of IC5a and IC5b, which are used as variable input resistors to the two integrator stages of the SVF. The varying bias is produced by the envelope shaper section IC3b, TR1 and associated components as follows:

Two sections of IC1 form a low-frequency clock oscillator, driving the 18-stage shift register IC2. The remaining two sections of IC1 provide Exclusive-OR feedback from stages 12 and 17 (pins 11 and 8 respectively) of the shift register, to its input at pin 1. This provides the longest possible PRBS (pseudo-random bit sequence) of 0s and 1s, repeating after $(2^{17})-1$ clock pulses. Although the frequency distribution of the sub-audio noise is white, its amplitude distribution is anything but 'Gaussian' or random, being at either logic 0 or 1. The low-pass filter action of passive integrator (R4 and C2), and active integrator (IC3b and associated components) turns the PRBS signal into the noise-like waveform shown in Figure 4a. This is used to drive the bias input, and hence control the tuning of the SVF when 'breeze' is selected, resulting in the general pitch of the the wind noise gently rising and falling in a realistic fashion. The inclusion of C8 in the Q-setting circuit results in the Q increasing when the low-pass filter tunes to a higher frequency, causing the strength of the wind noise to increase as the pitch rises and vice versa, adding to the realism.

For surf, a different envelope is required, see Figure 4b. On its larger positive-going excursions, the sub-audio noise waveform at pin 7 of IC3b turns on TR1 to a greater or lesser degree, which rapidly discharges C5. This results in the pitch of the noise out of the SVF dropping suddenly, simulating the breaking of a wave upon the beach. When TR1 turns off again, C5 slowly recharges through R13 and R14, raising the pitch of the noise out of the SVF, simulating the spent wave hissing through the stones as it recedes again. The high-pass surf output from the SVF then passes through three fixed passive low-pass sections, R35,C13, R36,C14 and R41,C16 before being fed via selector switch S1c to the amplifier. This has the effect of greatly emphasising the low-frequency energy which is passed by the SVF on the negative-going peaks of the surf envelope, producing a very convincing 'booming roar' just like a real

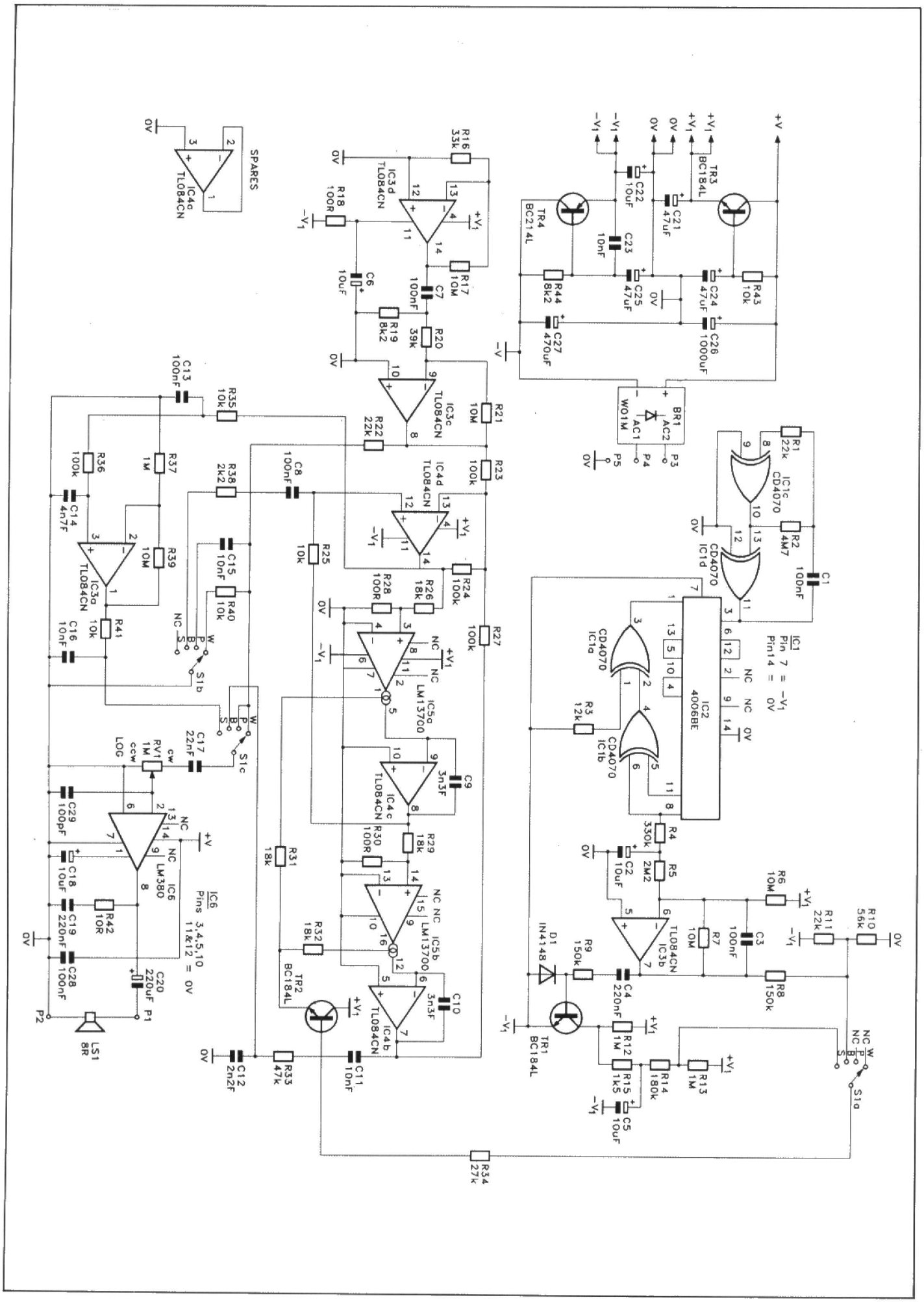


Figure 2. Circuit diagram of the EnviroSynth.

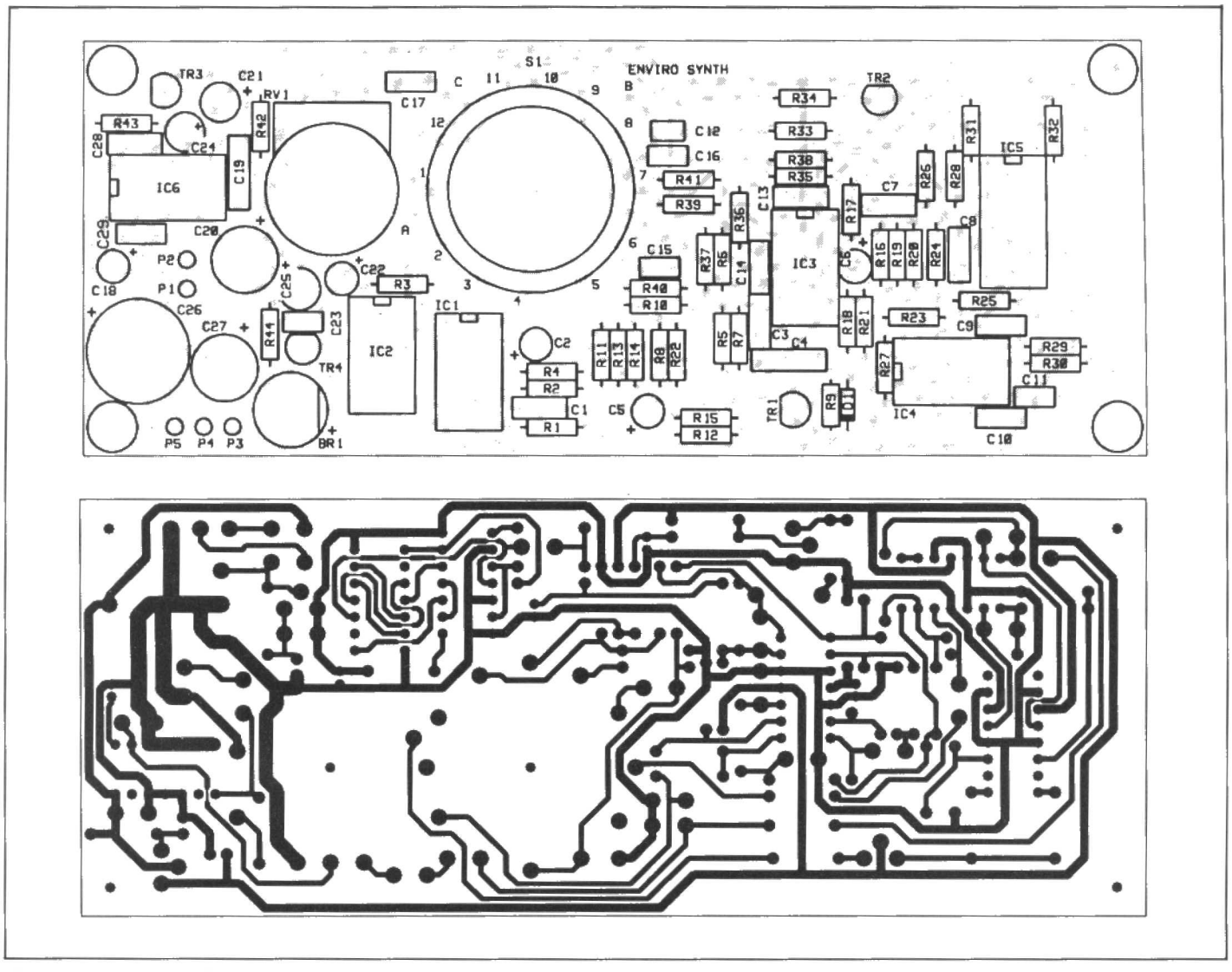


Figure 3. PCB legend and track.

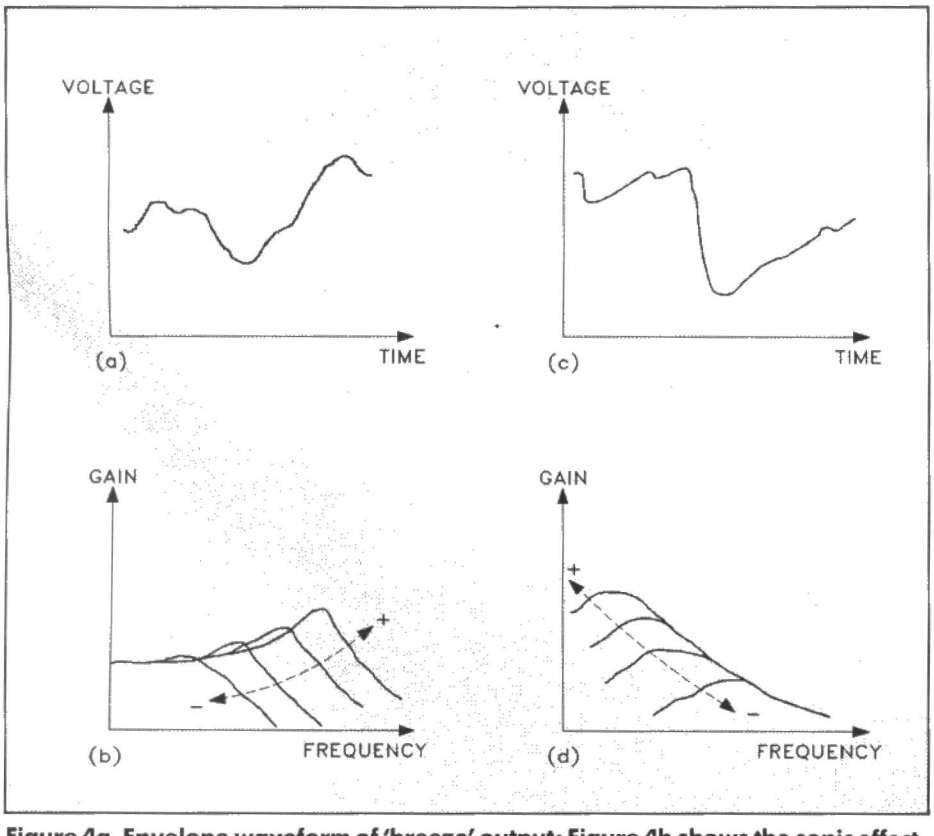


Figure 4a. Envelope waveform of 'breeze' output; Figure 4b shows the sonic effect. Figure 4c. Envelope waveform of 'surf' output; Figure 4d shows the sonic effect.

roller breaking.

The audio output stage is very straightforward, using the long-established LM380, an IC which has the advantage over some other audio amplifier ICs of needing very few extra components strung around it. The power supply, a straightforward split-rail design, is powered by a centre-tapped transformer with secondary windings of 6V-0-6V (our YN14Q is recommended). Note that NO mains components are supplied in the kit; this is left to you. In the interests of safety, a double-pole on/off switch and fuse MUST be used on the primary side of the transformer. In addition, any metalwork (including the transformer casing) MUST be earthed (a 3-core mains lead must be used, and the 13A mains plug must be fitted with a 3 amp fuse). In addition, it is a good idea to cover any exposed mains connections with PVC or heat-shrink sleeving. A diagram of the wiring at mains potential is shown in Figure 5. If you wish to run the unit off your own split-rail power supply (±7 to 11V DC), connections to the PCB are shown in Figure 6. An alternative to running the unit off mains voltage is to use two 9V batteries (e.g. alkaline PP3s) wired back-to-back, as shown in Figure 7. Note that in all cases, the loudspeaker, of impedance 8Ω, is wired to terminals P1 and P2.

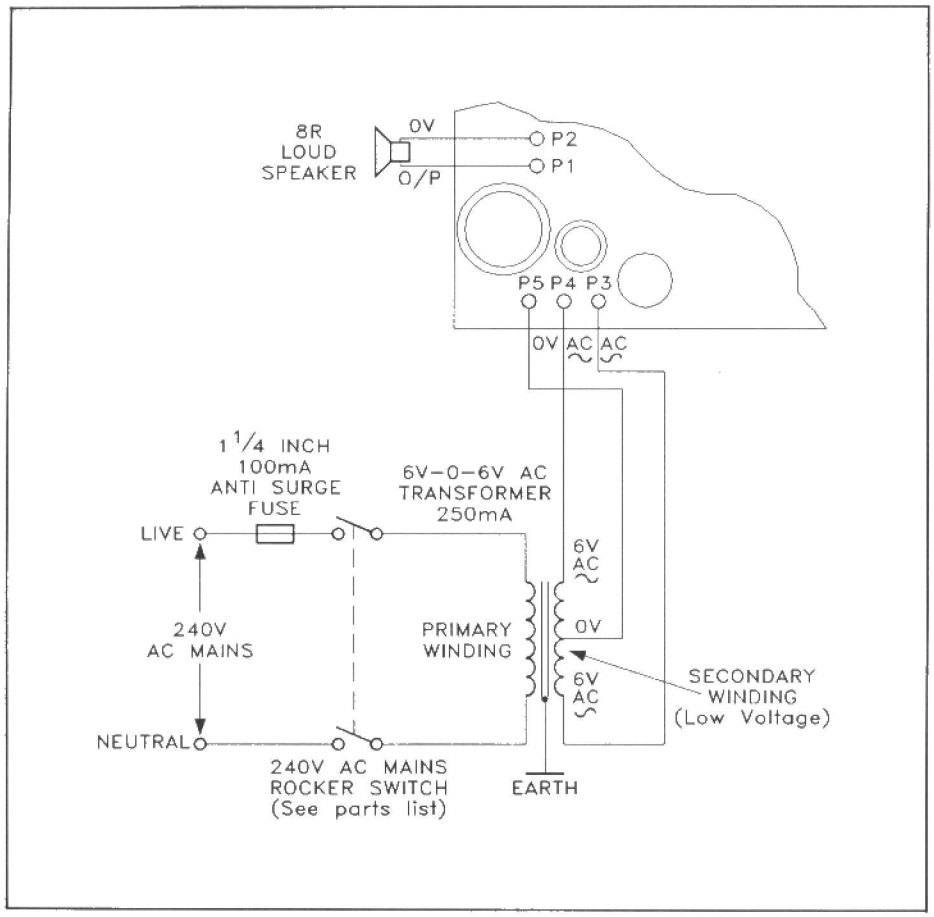


Figure 5. AC power supply (6V-0-6V AC RMS).

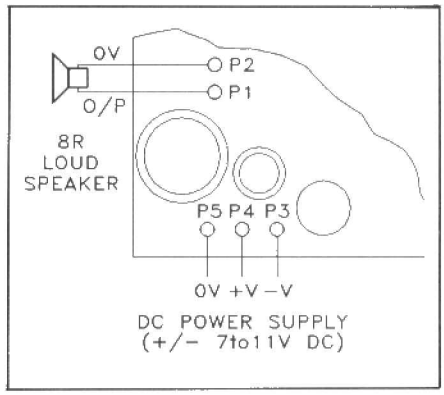


Figure 6. DC power supply.

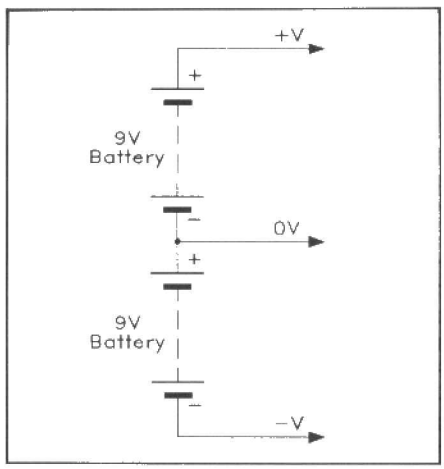


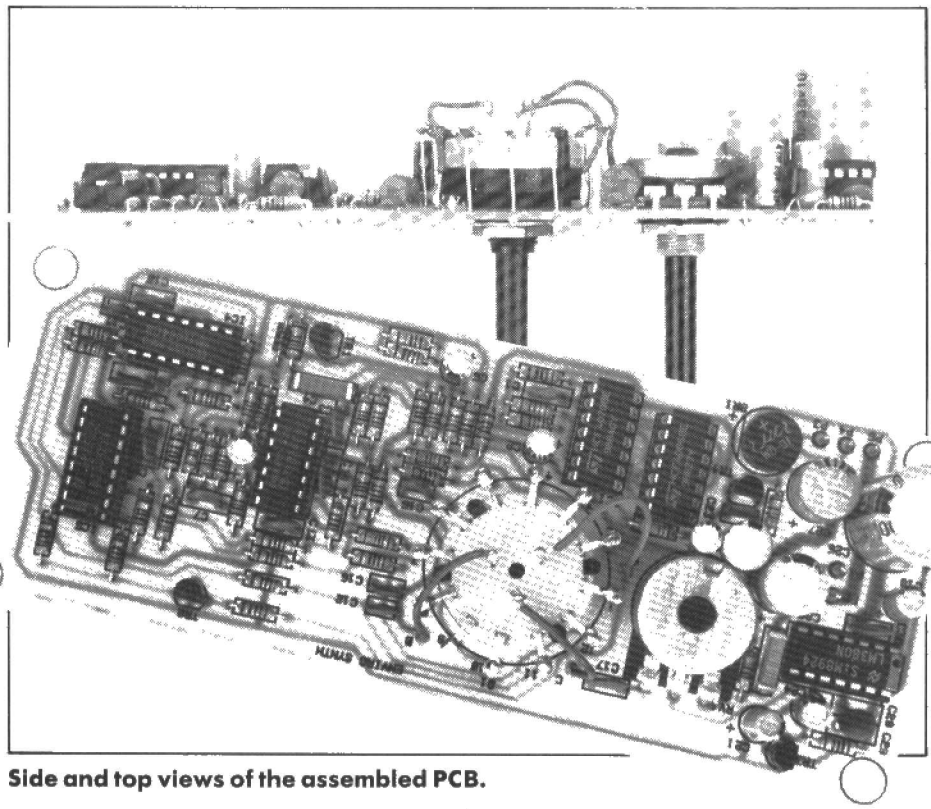
Figure 7. Using two 9V batteries.

Construction and Testing

Construction is very simple, since nearly all of the components are mounted on the PCB. Refer to the Constructors' Guide supplied with the kit for helpful practical advice. To aid assembly and orientation of the components, the high quality glass fibre PCB supplied with the kit has a silk-screened legend on the component side, see Figure 3.

It is best to mount all the low profile components first, followed by the taller items. Finally, the selector switch (S1) and volume control (VR1) should be fitted to the PCB. Before soldering, please check that each component is in the proper position and is correctly orientated (in the case of semiconductors and polarised components). If you intend to experiment with the sounds that the unit produces (see below), it is a good idea to fit PCB pins to the board where the legs of the original components would go. This will enable you to experiment without danger of damaging the PCB. When assembly is complete, test the unit; before powering up, double-check your work. If the unit fails to work when power is applied, check for solder bridges, incorrect or misaligned components.

It is important to note that, due to the very high gain provided by IC3c and IC3d, hum pick-up is likely to be experienced until the unit is mounted in a shielded case (which, for the prototype, was the loudspeaker enclosure of an old stereo record player). A strip of aluminum foil (as used in the kitchen) should be glued to the inside of the top of the case, and part of the way down one side. This foil should be earthed via the 0V rail of the circuit. This will provide an effective screen against hum pick-up, but great care should be taken to prevent components or wires shorting to it, particularly those at mains voltage.



Side and top views of the assembled PCB.

When complete and tested, the unit can be connected to the speaker (if not integral to the case), given a final operational check, and boxed up.

Customising

You may wish to experiment with different variants of the sounds available. There is

Range	Circuit Changes	Sonic Effect
Pink Noise	C15 increased to 22nF	'Mellower' sound
	5k6 resistor in series with C15 (22nF)	Closer approximation to pink noise
'Surf' sound	Change value of R9, R12 to R15	Affects way in which wave breaks on shore
	Change value of C5	Vary rate at which broken wave recedes down the beach
	Resistor of value 0 to 22kΩ connected between 'B' and 'S' of S1b	'Peakiness'
'Breeze' sound	Change R8	Varies degree of variability in wind strength
	Change R10	Varies general pitch of wind noise
	Change R38	Increase to give gentle breeze. Decrease to simulate gales!

Table 1. Summary table of customisations.

really nothing you can do to the white noise without making it non-white, but the pink noise can be tailored somewhat. Increasing C15 to 22n will move the break point down to 400Hz, resulting in a mellower, if less 'pink', sound. If you additionally insert a 5k6 resistor in series with C15, the top-cut will be cancelled above 1600Hz, giving an even closer approximation to true pink noise. However, it is when you start to experiment with the 'surf' and 'breeze' sounds that the fun really starts!

It will be found that for the 'surf' sound, the changes which have most affect on the result are those which modify the envelope. Changing C5 will affect the rate at which a wave which has broken recedes down the beach, whilst R9 and R12 to R15 will all affect the way in which it breaks in the first place. A further possibility is to increase the Q of the high-pass filter by connecting a resistor in the range 0 to 22kΩ between contacts B and S of S1b. In the case of the 'breeze' range, increasing R8 will reduce the degree of variability in the strength of the wind, and vice versa. Decreasing R10 will increase the general pitch of the wind noise, and vice versa. However, the most dramatic changes are brought about by changing R38. Increasing its value will result in a very gentle woodland breeze sound, whilst decreasing it to 1kΩ (or even less) will make the wind sound more and more tempestuous.

A range of very interesting sounds is attainable – so go ahead and have fun with this really novel circuit!

ENVIROSYNTH PARTS LIST

RESISTORS: All 0·6W 1% Metal film (Unless specified)

R1,11,22	22k	3	(M22K)
R2	4M7	1	(M4M7)
R3	12k	1	(M12K)
R4	330k	1	(M330K)
R5	2M2	1	(M2M2)
R6,7,17,21,39	10M	5	(M10M)
R8,9	150k	2	(M150K)
R10	56k	1	(M56K)
R12,13,37	1M	3	(M1M)
R14	180k	1	(M180K)
R15	1k5	1	(M1K5)
R16	33k	1	(M33K)
R18,28,30	100Ω	3	(M100R)
R19,44	8k2	2	(M8K2)
R20	39k	1	(M39K)
R23,24,27,36	100k	4	(M100K)
R25,35,40,41,43	10k	5	(M10K)
R26,29,31,32	18k	4	(M18K)
R33	47k	1	(M47K)
R34	27k	1	(M27K)
R38	2k2	1	(M2K2)
R42	10Ω	1	(M10R)
RV1	Log. Pot 1M	1	(FW28F)

CAPACITORS

C1,3,7,8,13,28	Minidisc 100nF 16V	6	(YR75S)
C2,5,6,18,22	PC Elect 10μF 50V	5	(FF04E)
C4,19	Poly Layer 220nF	2	(WW45Y)
C9,10	Ceramic 3n3F	2	(WX74R)
C11,15,16,23	Ceramic 10nF	4	(WX77J)
C12	Ceramic 2n2F	1	(WX72P)
C14	Ceramic 4n7F	1	(WX76H)
C17	Ceramic 22nF	1	(WX78K)
C20	PC Elect 220μF 35V	1	(JL22Y)
C21,24,25	PC Elect 47μF 25V	3	(FF08J)
C26	PC Elect 1000μF 35V	1	(FF18U)
C27	PC Elect 470μF 16V	1	(FF15R)
C29	Ceramic 100pF	1	(WX56L)

SEMICONDUCTORS

D1	1N4148	1	(QL80B)
TR1,2,3	BC184L	3	(QB57M)
TR4	BC214L	1	(QB62S)
IC1	4070BE	1	(QX26D)
IC2	4006BE	1	(QX03D)
IC3,4	TL084CN	2	(RA72P)
IC5	LM13700N	1	(YH64U)
IC6	LM380	1	(QH40T)

MISCELLANEOUS

BR1	W01	1	(QL38R)
S1	Rotary SW4	1	(FH44X)
P1-5	Pin 2145	1 Pkt	(FL24B)
	PCB	1	(GH10L)
	DIL Socket 14-Pin	5	(BL18U)
	DIL Socket 16-Pin	1	(BL19V)
	Instruction Leaflet	1	(XT63T)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

6W Elliptical Speaker	1	(GL17T)
250mA Transformer 6V	1	(YN14Q)
1¼in. Clickcatch F/H	1	(FA39N)
Fuse 1¼in. A/S 100mA	1	(UK58N)
Dual Rocker Neon Red	1	(YR70M)
Min. Mains Black Cbl.	2m	(XR01B)
SR Grommet 5R2	1	(LR48C)

The Maplin 'Get-You-Working' Service is available for this project.

The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.

Order As LP67X (EnviroSynth) Price £14.95.

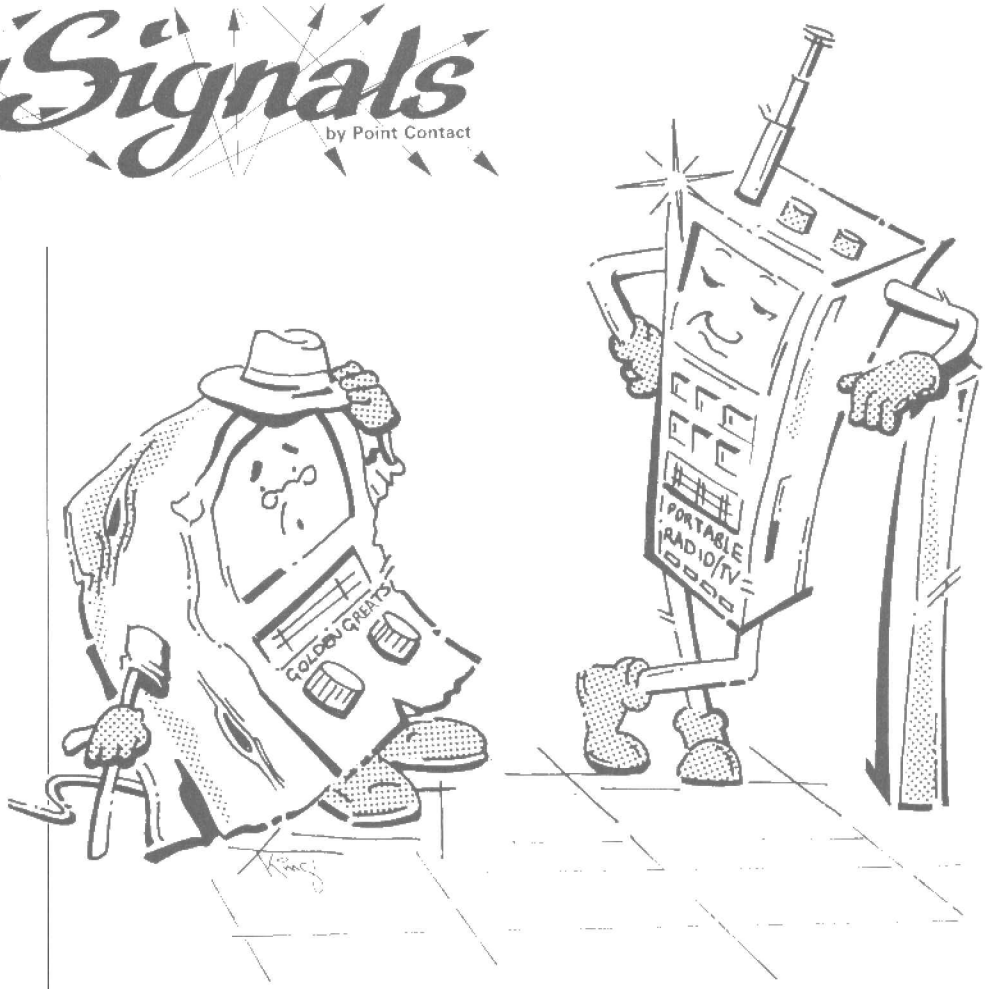
Please Note: where 'package' quantities are stated in the Parts List (e.g. packet, strip, reel etc.), the exact quantity required to build the project will be supplied in the kit.

The following new item (which is included in the kit) is also available separately, but is not shown in the 1992 Maplin Catalogue.

EnviroSynth PCB **Order As GH10L Price £3.95.**

Stray Signals

by Point Contact



Late last year PC attended an IEE Colloquium on Direct Digital Synthesisers at Bradford University. This entailed a trip 'oop North' from our home in the South of England, and me and the missus (sorry, the missus and I) took the opportunity to visit friends in York, staying on for a few days afterwards. We visited the ruins of Fountains Abbey and, in the City of York itself, we toured the Shambles and other delightful byways, buying some gorgeous Beamerdale goat's cheese at one of the many delicatessens, and a copy of 'Modern TV Circuits and Fault Finding Guide' (Bernard's Radio Manuals No. 142) at one of the many bookshops. The latter cost me 12p, much less in real terms than the original price of four shillings and sixpence. The final upshot of the visit was that PC acquired two non-operative valve radios of '50s vintage, which had been taking up room in our friends' house to no good purpose for a good while.

On our return to Hampshire, barely a day had passed before PC could no longer resist trying out the sets, despite all the other things he should have been getting on with, like writing this instalment of Stray Signals. One of them, a MW/LW Philips model B2G0?? (part of the manufacturer's nameplate label was missing), sounded completely dead, although the valves lit up and I soon found out the hard way that the rectifier was producing a good 300V HT. The set was an early example of printed circuit construction, and the track from the rectifier cathode to the smoothing capacitor ran right along the rear of the PCB, which I would use to pick the set up – having of course unplugged it from the mains first, as AC/DC valve sets have no transformer to isolate the circuitry from the mains. Clearly the output stage was drawing no current, as the voltage across the Radiospares replacement smoothing capacitor, which someone had fitted at some time, was not being drained down at switch-off. But the primary of the output transformer was not open circuit, so further investigation was called for. Unfortunately PC's book of valve data did not include the range of valves used in this set, so it looked as though he was condemned to the tedium of working out the base connections with the aid of an eye-glass, something one can do with miniature glass based valves, but not with the earlier octal types or the later transistors! However, using lateral thinking, it was clearly a case for a call to Les, PC's friend since junior school days. Now when Charlie, radio repairman extraordinary and purveyor of earthy northern humour, eventually retired, he gave all his radio repair data sheets and books to Les. Some years ago the wireless section of the Chalk Pits Museum at Amberley advertised requesting the donation of such data and Les duly obliged. But evidently he still has a useful store himself, as he was able to ring me back a few minutes later to say that he had unearthed servicing sheets for both the Philips B2G05U (as it turns out) and my other acquisition, a Bush type A.C.11. So I now await with impatience the photocopies he has promised to send me.

Now don't get the idea that PC is interested only in electronic antiquities, otherwise why would he have gone to that Colloquium at Bradford? For instance, I read with interest in an advertisement that the Hughes Aircraft Company has developed a technique for producing on semiconductor chips 'distinct lines approximately one two-millionth of an inch' (interesting that the USA is finding metrication so difficult). These ultra-small features, which are produced with a beam of ions rather than electrons, are 100 times finer than those used in most current ICs, and promise a tenfold speed increase in due course.

Nor are PC's interests confined to light-current electricity – to electronics. The 'heavies' play an important part in all our lives, producing the electricity without which our circuits won't work, and in the process producing a good part of the carbon dioxide which the experts tell us will cause global warming, turning much of the land into desert and melting the polar ice to drown most of the rest with a disastrous rise in sea level. So it was again with interest that I read in the Journal of the IEE, Sept. 1991, that a commercial wind farm near Delabole, rated at 4MW, is due to start working early in 1992. And about time too: on several visits to Denmark, I have seen a number of such wind farms; the Danes are far ahead of us in this respect.

Yours sincerely,

Point Contact

FINISHING OFF

PART TWO
by David Smith

Last month, we looked at choosing a suitable case for your project, as well as the finer details of how and where to drill the various holes required. This month, we will consider several techniques which help when actually building the Maplin kits required for this project. We will also look at how you can give the inside of this, and other projects, a more professional look.

Building the Maplin Kits

All the necessary instructions for the building of Maplin projects are supplied with the kits themselves when purchased. However, as we are looking specifically at how to 'fine tune' the *appearance* of our work, we need to study carefully the various constructional techniques involved.

Let us start with the power supply board. Presets RV1 and RV2 should not be fitted onto the PCB, as voltage output levels will be controlled by the two potentiometers fitted to the front panel. This modification is shown in Figure 1. The bolt used for fixing the toroidal transformer to the PCB can be cut down in length so that it becomes flush with its fixing nut, giving the assembly a much neater overall appearance (see Photo 1).

The end of the bolt can be filed flush to the top of the nut after cutting, so that there are no sharp edges, which are a potential source of injury and/or damage. Wiring to the toroidal transformer can be made much neater by using a small amount of spiral cable-wrap to enclose it. Notice, from Photo 2, that the two orange wires (240V AC Input) are brought out half-way along this wrap. This enables them to be connected to the mains on-off switch. The spiral cable-wrap has also been attached to the transformer casing with adhesive tape, rather than being allowed to just settle untidily anywhere.

Additional wiring to the PSU has been implemented using ribbon cable. This particular cable has the advantage of being able to lie flat on the PCB's top surface, as shown in the photograph. It is supplied in 10, 20 or 30-way widths and, depending

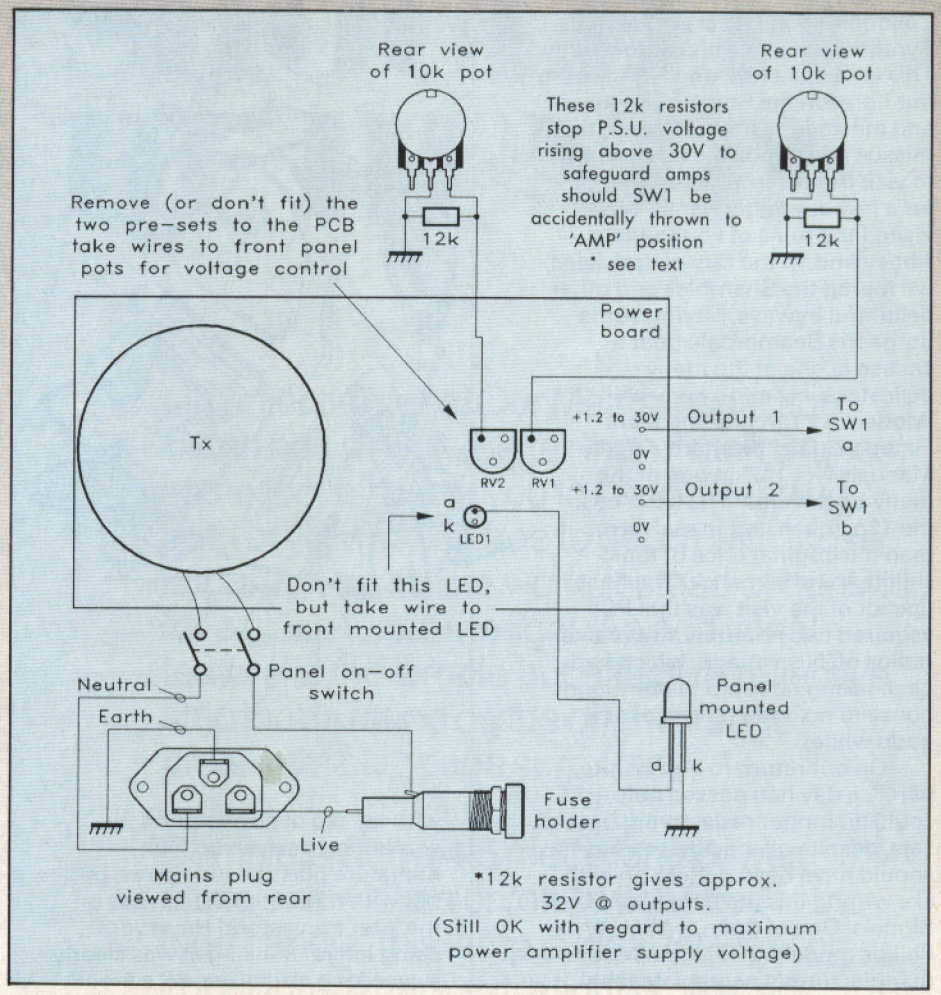


Figure 1. Modifying the PS board to give two user-controllable variable voltage outputs.

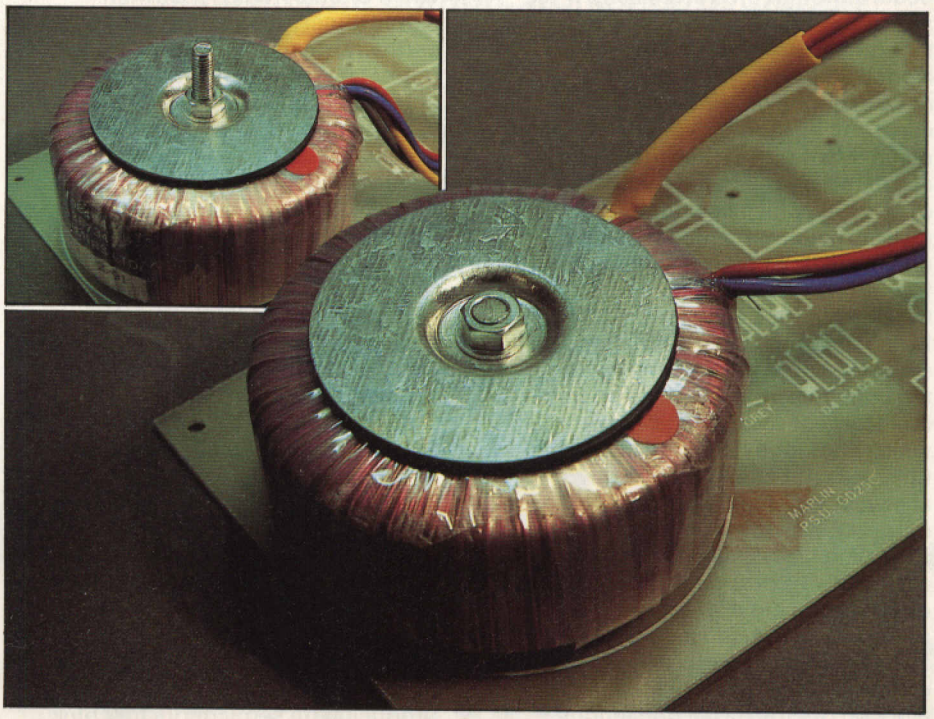
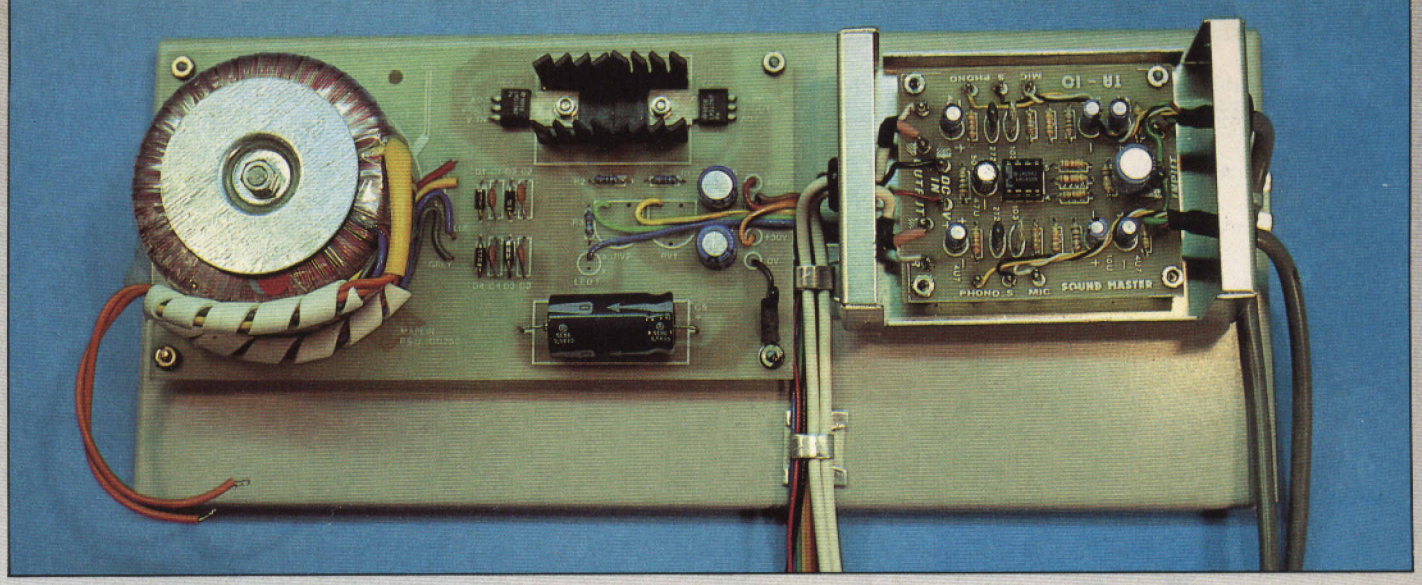


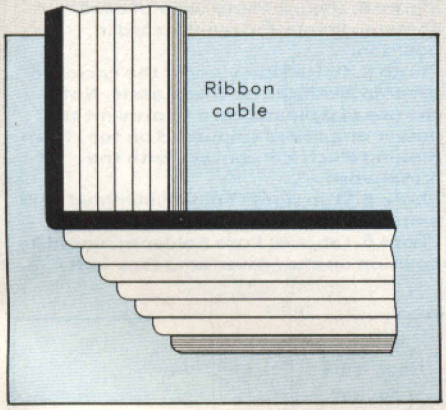
Photo 1. Inset photo shows that the transformer bolt is too long, while the main photo shows the bolt cut to size and filed flat – for a more pleasing visual appearance.

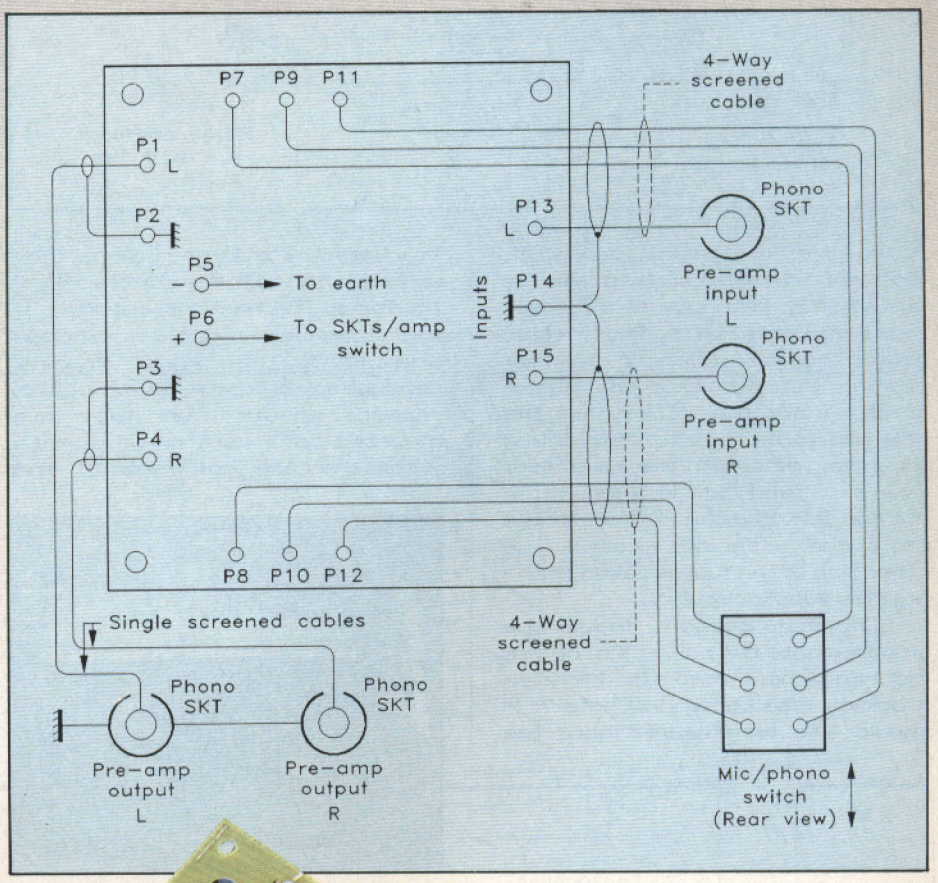


on your requirements, the outer insulated wires can be peeled off, leaving you with just the right number of conductors for the job in hand. Of course, when having to turn a corner with the ribbon cable, it is much neater to fold it through 90°, than forcing it around a bend whilst striving to keep it flat at the same time. This is shown in Figure 2.

Stereo Preamp Kit

Building the stereo preamp kit (see Photo 3) should pose no problems. However, it is important that the circuit board is mounted inside a metal box for screening purposes.





Two lengths of four-way screened cable are used to carry the input and microphone/phono switching circuitry. Figure 3 shows how the preamp is wired up. Make sure that you only earth the screening at one end of this cable, to avoid any earth-loop problems. You should follow this practice of only earthing one end of a screened cable throughout the whole project, and indeed any audio-related project that you may be considering. Fit the finished PCB inside the metal box and mount it onto the chassis as shown in Figure 4. Finally, glue a piece of plastic card onto the top surface of the preamp box, to prevent the power-amp modules (mounted on top) from making electrical contact with the metal case (see Photo 4 and Figure 5).

Audio inputs and outputs to the preamp are made via phono sockets mounted on the front of the case. There is also a 5-pin DIN socket which echoes these connections. Using two phono plugs wired with a short length of screened cable, it is possible to connect the outputs of the preamplifier to the inputs of the power amps. However, because all phono sockets are independently wired, total flexibility exists between all inputs and outputs, which is just the sort of thing you want on a bench-test unit.

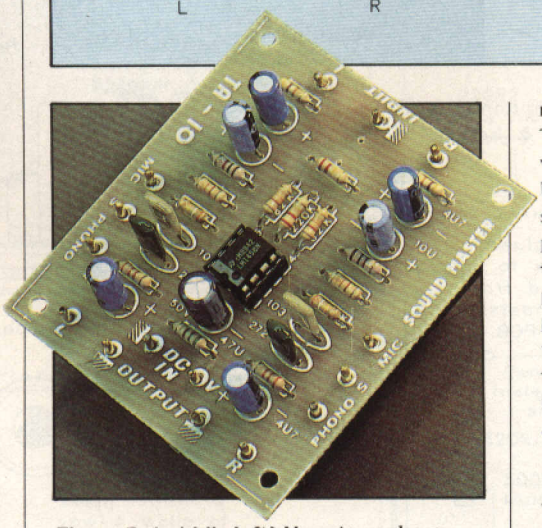
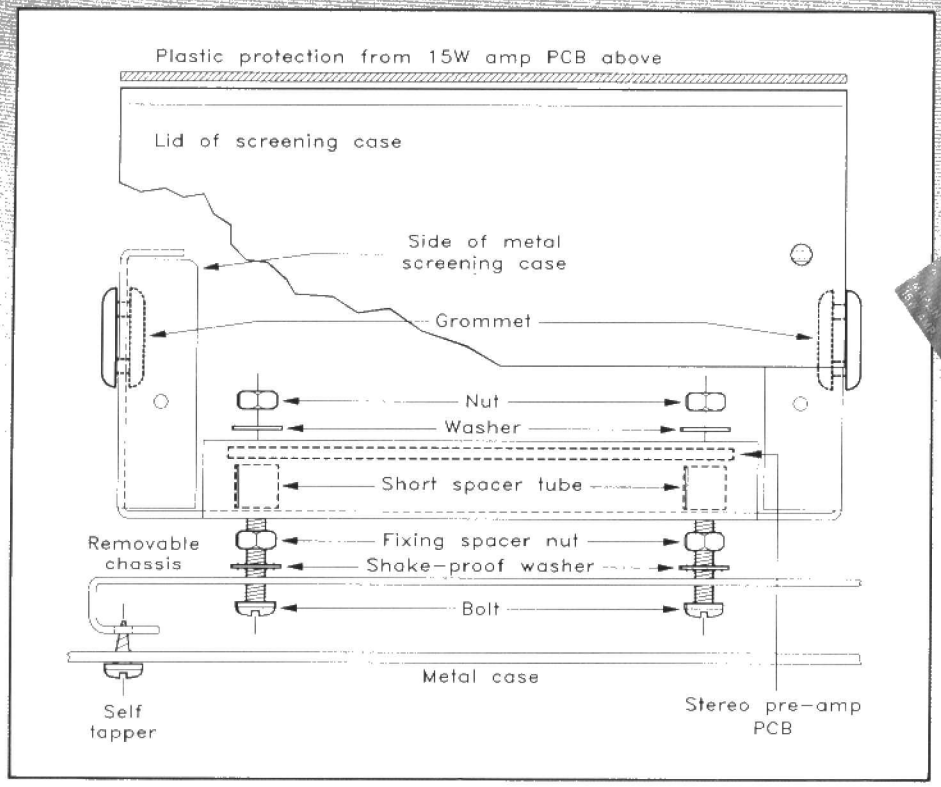
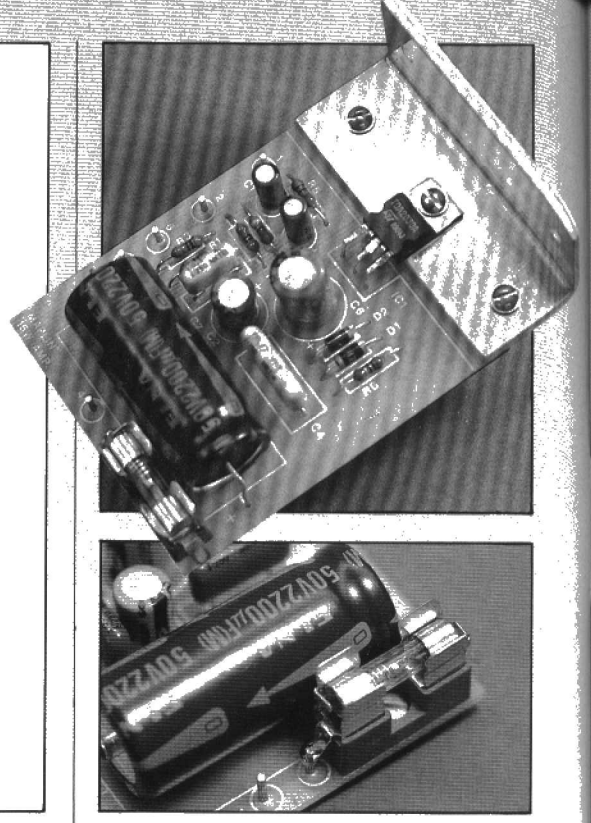


Figure 2. (middle left) How to make a ribbon cable run at right-angles to its previous direction of travel.
Figure 3. (middle right) Stereo preamp wiring details.
Photo 2. (top) The power supply board and preamp, mounted on a separate metal chassis supplied with the case.
Photo 3. (above) Fully assembled preamp kit.

15W Power Amplifiers

The two 15W power amplifier boards (one of which is shown in Photo 5) have to be slightly modified before fitting. For safety, a 1A anti-surge fuse has been added to the PCB of each amplifier (see Photo 6). The fuseholder has been located just to the right of PCB pin 3, which is the positive rail supply





voltage pin. The easiest way to fit the fuseholder is to firstly position it on the PCB, with one of its solder tags placed over pin 3. Then, whilst holding the fuse holder in the correct position (as shown in the photograph), mark the PCB where the hole has to be drilled. After drilling this hole, re-position the fuseholder over pin 3, and fix it in place with a nut and bolt. You can then solder the tag of the fuseholder to pin 3. The other side of the fuse is taken to the positive supply circuitry.

Thermal grease should be smeared onto the power ICs, before mounting them onto the heatsink brackets – as shown in Photo 7. It should also be smeared onto the brackets themselves, before they are attached to the metal chassis of the case. The heatsink brackets of each amplifier must be in close proximity to the case for thermal conduction to be effective. For this reason, ensure that they are mounted on a bare metal surface within the case (see Photo 8). The audio output from the power amplifiers is taken via the headphone socket to two different types of speaker sockets on the rear panel; a pair of DIN sockets, and two pairs of 4mm sockets.

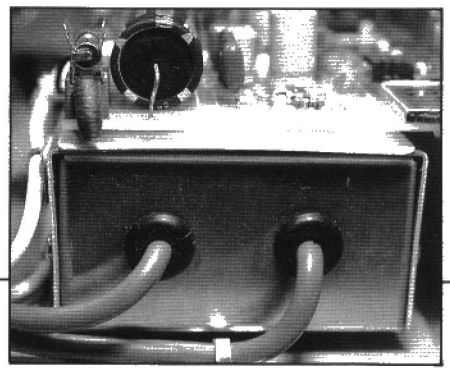
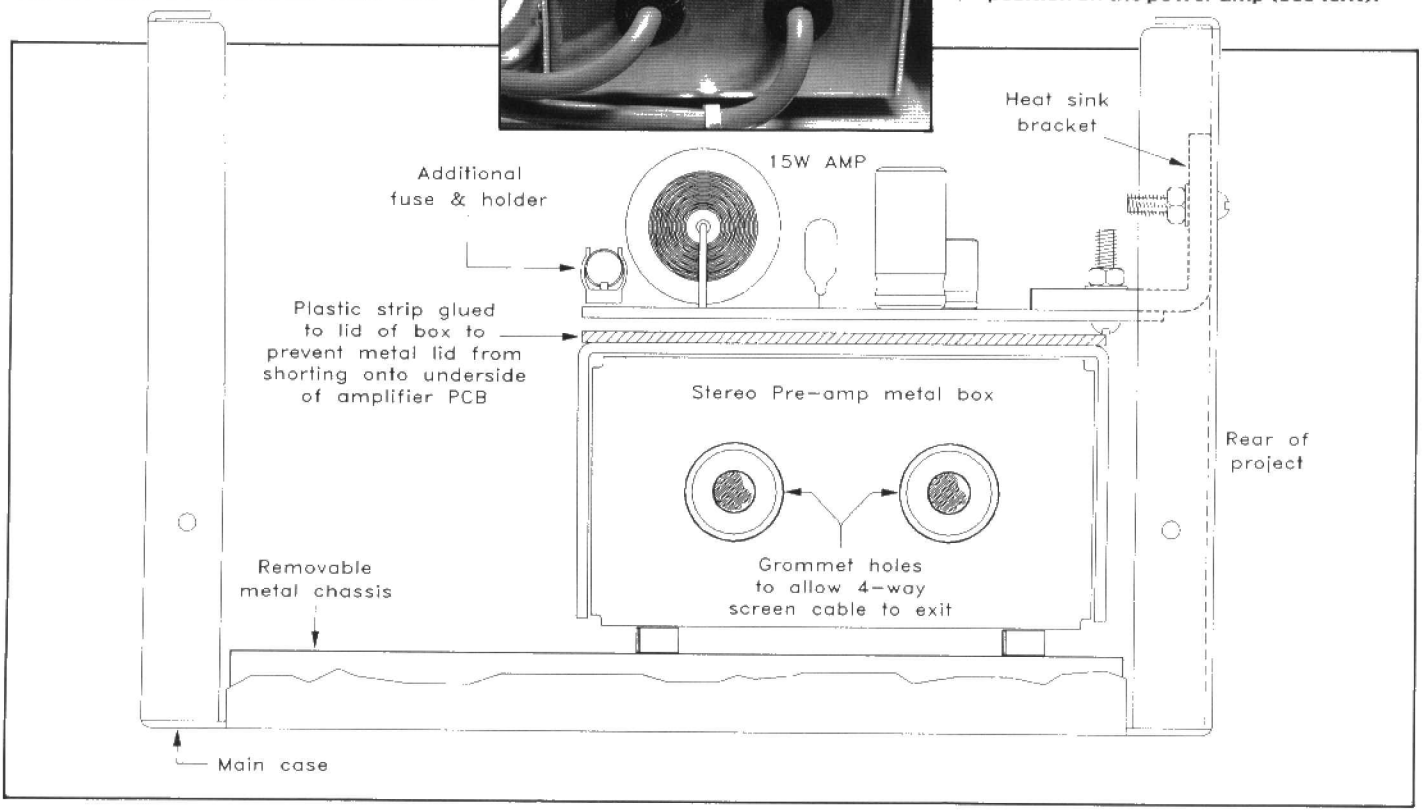
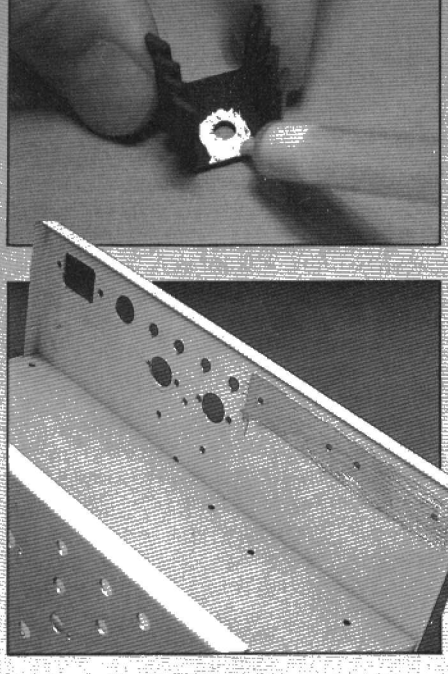


Figure 4. (top left) Fixing the preamp and its screening case onto the main chassis.
Figure 5. (below) Side-view of case, showing insulating plastic card in position.
Photo 4. (left) Side-view of the enclosed preamp mounted on the chassis. Note the use of a plastic card to prevent the power amplifiers (mounted on top) from making electrical contact with the metalwork.
Photo 5. (top right) Fully assembled 15W amplifier kit.
Photo 6. (above) Fuse holder mounted in position on the power amp (see text).


Heat sink bracket
15W AMP
Additional fuse & holder
Plastic strip glued to lid of box to prevent metal lid from shorting onto underside of amplifier PCB
Stereo Pre-amp metal box
Rear of project
Grommet holes to allow 4-way screen cable to exit
Removable metal chassis
Main case



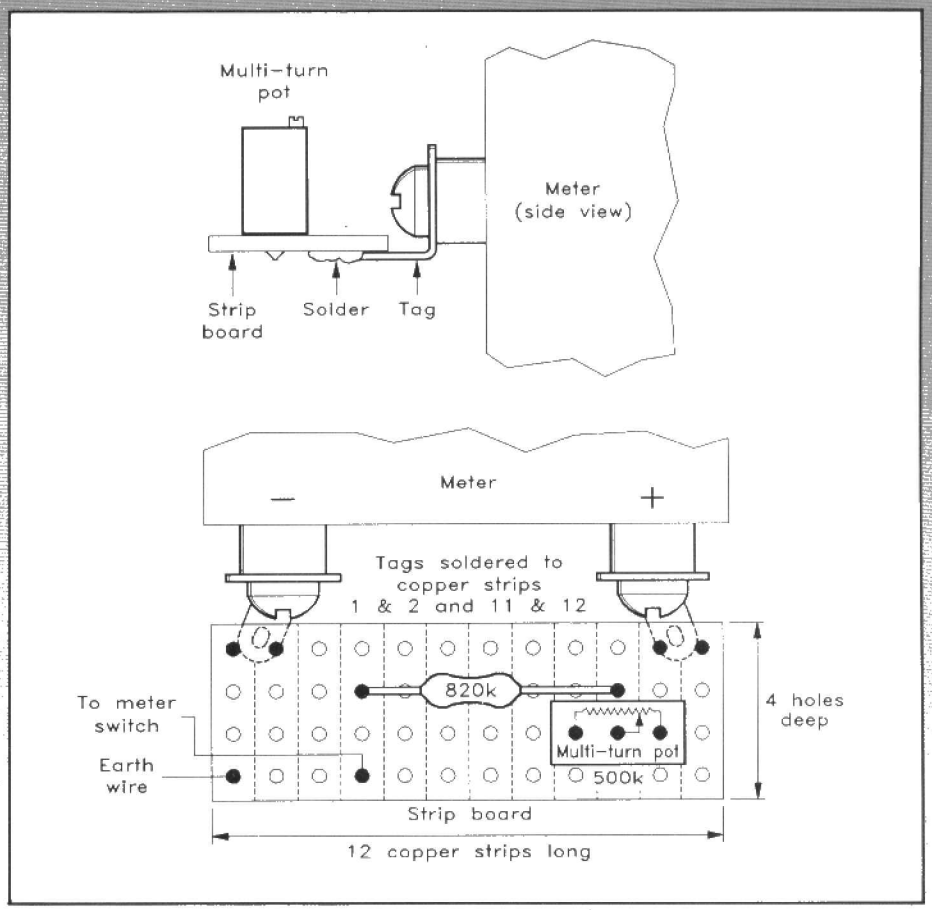
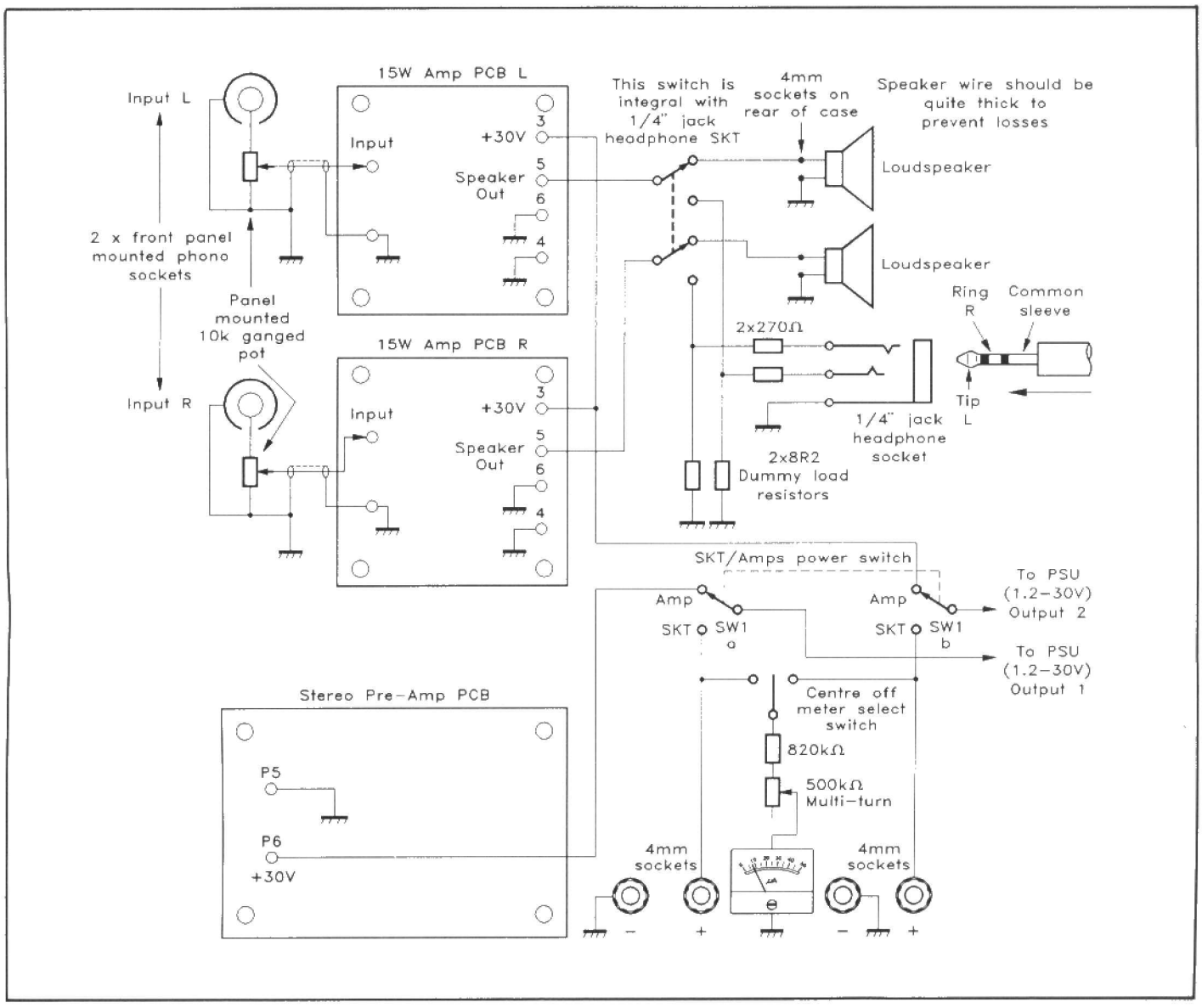


Figure 6. (below) Preamp and power amp wiring diagrams.
Figure 7. (top right) Mounting the stripboard on the meter.
Photo 7. (top left) Applying heat transfer compound (order code FL79L) to the heatsinks of the 15W amplifiers.
Photo 8. (above) Close-up of the area of the case where paint has been scraped away. This will help to ensure adequate heat transfer when the amplifier heatsinks have been bolted on.



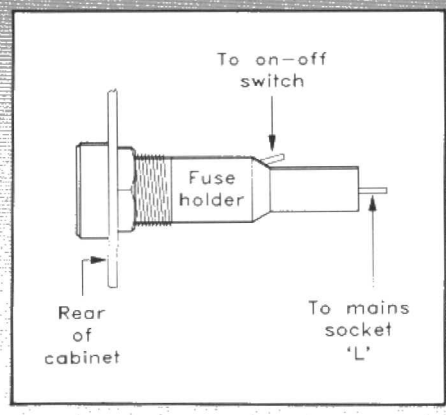
When using headphones, the action of plugging them into the headphone socket switches the outputs of the power amplifiers away from the rear sockets, to a pair of dummy-load resistors mounted on the rear of the case. Obviously, the headphones should not be fed with full power from the amplifiers – for this reason, two 270Ω 1W resistors have been fitted to the headphone socket, in order to reduce power to a more comfortable level! These modifications are shown in Figure 6.

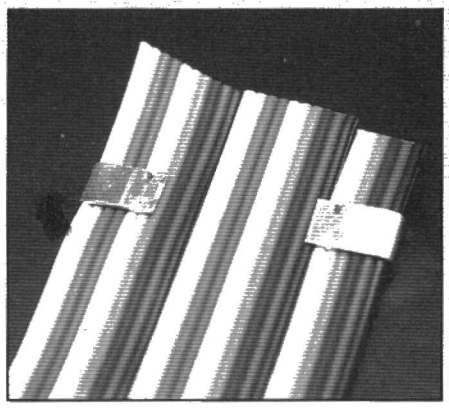
Both the preamplifier and the two power amplifiers require a power supply of 30V. This is provided by the internal power supply board, and is offered to the amplifiers via a front-mounted switch. This switch can select between the amplifier mode, and that of providing a variable supply to the front-panel mounted 4mm sockets. However, because the PSU is capable of supplying more than 30V, it has been necessary to incorporate two voltage limiting resistors into the circuitry (see Figure 1). These have a value of 12kΩ, and are wired across the two voltage control pots. With these two resistors out of circuit, around 40V could be present at the 4mm sockets. Should you then accidentally move the 'SKTS/AMP' switch across to the 'amplifier' position, with almost 40V on line...! The choice is yours. Personally, considering there are so few occasions where one would need a power supply capable of delivering more than 30V, I think I would prefer to keep my amplifiers!

Panel Meters

The meter has been provided on our project so that output voltages can be set and monitored. It is switchable between the two independent outputs, and also has a centre 'off' position if you do not require it. Turning a 50μA panel meter into one that can read voltage requires a series resistance to inserted into one of the meter's supply lines. It is virtually impossible to obtain a resistor of precisely the right value, so it has been necessary to use one of 820kΩ in value, wired in series with a 500kΩ multi-turn pot. This configuration allows the meter to be set up correctly. To carry out this task, simply place an accurate voltmeter across one of the two supply outputs, and adjust the multi-turn pot so that the panel meter reads the same voltage as your voltmeter. Both the series resistor and the multi-turn pot have been mounted onto a small piece of stripboard, which is soldered onto the rear of the meter assembly – see Figure 7.

Make sure that you wire up the fuse holder correctly. The live wire, coming from the mains socket, should go to the *rear-most* connection, as shown in Figure 8. This is because you will be prevented from receiving an electric shock, should you inadvertently attempt to change the fuse whilst the unit is still connected to the mains – the 'live' terminal of the fuseholder is at the rear, away from prying fingers.





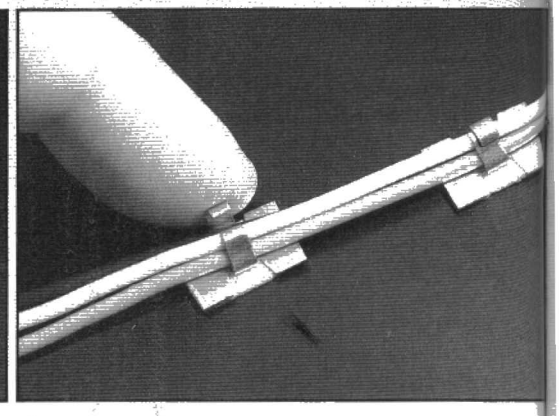


Figure 8. (top left) The safe way to wire up a panel-mounting fuse holder.
Photo 9. (above) Self-adhesive cable clamps

Striving to make your projects look more professional also dictates that all components should be mounted onto the printed circuit boards with the utmost care. Make sure that components are seated well down onto the board, rather than being mounted slightly away from it. There is nothing worse than seeing components leaning in different directions, with differing lengths of lead-out wire disappearing through the holes in the PCB. Why not call them all to attention? Sit them up straight and make your boards look that extra bit smarter!

When wiring up a project, there is a great temptation to join the various points that need connecting, using the shortest possible route. Doing it this way is obviously speedy, and providing that the wires are carrying undemanding currents, voltages or frequencies, the project will probably work. Unfortunately, it looks downright awful. Even software houses, when designing computer-aided design packages, have given this somewhat untidy concoction of random wiring the ignominious title of 'ratsnesting', simply because that's what it looks like! It may take longer to run a wire 'up hill and down dale' when getting it from point 'A' to point 'B', but it will pay off in the long run, making for a much neater job. It also has the advantage of making any future fault-finding sessions to be done in a much more straightforward manner.

Assisting you in tidying up those wires are a wide variety of little helpers, all waiting to give your project that extra special look, so let's get started by taking a closer look at the pros and cons of what's on offer.

Cable Clamps

These come in a variety of shapes and sizes, two of which are shown in Photo 9. Usually made of aluminium, and having a self-adhesive backing, they offer a quick and simple way of clamping cables. There are also wider versions available for multi-way ribbon cable. Generally, clamps are not suitable for any cabling where there is a possibility of strain, as they have a fairly weak gripping action and are therefore best suited to lightweight internal use. If you decide to use this type of clamp, try not to force too many wires into it – use a larger one, if necessary. The fact that clamp arms can be easily prised open is an advantage if you need to run further wiring along the same route in the future.

Cable Ties and Bases

Cable ties are very strong, and make an ideal way of holding wires together. To use one, encircle the bundle of wires with the tie, and then pass the end of the tie through the gripper, located at its other end. This is rather akin to threading a needle. After passing the end through the gripper, pull it tight so that the wires are held firmly together. Be careful though, because cable ties have enormous strength and can easily be overtightened, causing undue stress to be placed on the cables.

Finally, snip off the excess piece of tie close to the clamp. Most ties are irreversibly self-locking, and therefore impossible to remove without having to first destroy them. If you are using this type, then make sure that all of your wiring has been completed beforehand. Alternatively, Maplin offer a range of re-usable cable ties, the operating principles of which are identical to those of the ordinary ones, except that a lever is included

which, if depressed, releases the latch. All ties, whether locking or non-locking, come in a variety of lengths from 102 to 370mm.

Should you require your cables to run close to and along a surface, then fasten your cable ties to bases, attached to the surface. There are two types of cable tie base; one which has a self-adhesive backing, and a second which utilises a screw for fixing. Photo 10 shows the self-adhesive type.

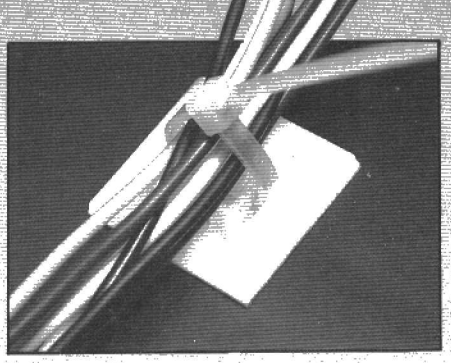
Spiral Cable Wrap

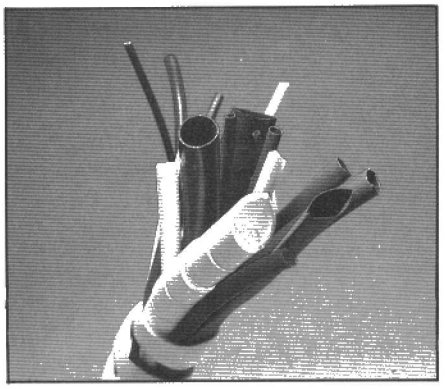
Clearly visible on the transformer shown in Photo 11, this is an expandable polythene spiral binding which simply wraps around the cable form, gripping it tightly. Should you wish, wires can be led out of the wrap at any point along its route. Cable wraps are a bit tricky to use in confined spaces so, if possible, make up any required looms beforehand. It is available from Maplin in three diameters; ½in., ¼in. and ⅛in.

Lacing Cord

Lacing cord has been around for many years. If you've ever looked inside an old valve wireless, or taken apart some ex-military equipment, then you will have very probably seen it holding the various wiring looms together in a neat and tidy fashion. It used to be made from wax-covered cord, but is nowadays made from a high-grade tubular nylon-cored cord, covered with a flexible PVC coating. It is easier to use than it is trying to describe how to use it! If you've learnt your knots as a Boy Scout (or Girl Guide!) it helps, but basically the intention is to encircle the wiring loom at suitable intervals with the cord, to keep the loom together. Don't cheat by cutting off small lengths of cord and tying individual knots in it at each position – it is far better and neater (and professional!), to use it as one complete length from start to finish. Begin by tying the cord securely to one end of the loom. Work along the loom, looping and knotting the cord as you go, keeping the wires tightly together. Finally, make another secure knot at the far end of the loom and cut off any excess. Place a small drop of glue or nail varnish onto each knot, which will stop it from becoming undone. Practice a few times before committing your 'skills' to your project. If it is done well, it provides a very neat and cheap way of keeping your wiring orderly.

Speaking of orderly wiring, there is something that needs to be done even before the process of connecting the various components together begins, and that is to straighten out the connecting wire. It is likely that your wire has been coiled up, twisted, kinked or whatever, and will therefore be in no fit state to be used (unless you live in an enormous mansion and store your wire in straight lengths!) Removing any bends or kinks is quite straightforward really. All you have to do is to place the wire on the floor, stand on one end of it, and pull it gently but firmly from under one of your shoes, taking it through a 90° bend in the process. I must stress the words 'gently but firmly', as it is quite easy to be too aggressive with it and over-stretch the wire, causing it to lose its physical properties. Only do this with single or multi-strand connecting wire – do not attempt it with screened, multi-core, or coaxial cable.





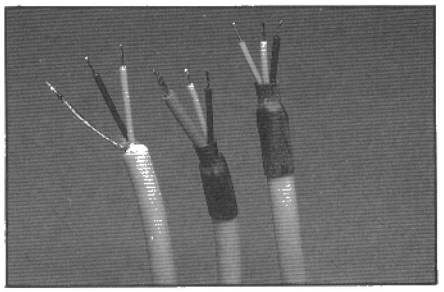


Photo 10. (top left) Wires being held in place by a cable tie. Note the use of a self-adhesive base, which enables the wires to be tidily run along a surface.
Photo 11. (above) Two close-up views of the internal wiring of the completed project. Note the use of rubber sleeves to cover the terminals.
Photo 12. (left) This shows several types of spiral-wrap, PVC and heat-shrink sleeving that are available to the home constructor.

Photo 13. (above) This shows three ways in which a cable could be formed, and the varying degrees of neatness. From left to right: 1. No sleeving and earth left uncovered; 2. Sleeving has been applied to both the earth screen and to the wire overall, forming a much neater appearance; 3. This shows a further refinement, where the earth screen connection has been formed by using a short, PVC covered, fine wire, connected to the main cable screen. This makes it of equal diameter to the other two wires – useful when they are being soldered to the PCB. A rubber sleeve covers the soldered joint.

Cable Connections

Using single-core wire is easy. Having made sure you have not stripped off too much insulation, solder the wire into place and cover the connection with a short piece of sleeving (remember to thread the sleeving onto the wire before soldering). Screened cable is a little more difficult to keep tidy, and it is advantageous to utilise some heat-shrink sleeving here – see Photo 13. Bare the outer covering of the screened cable first, and then twist the strands of earth wire together.

Slide a piece of ordinary plastic sleeving over the twisted strands, followed by a piece of heat-shrink sleeving over the entire cable (see diagram). Apply heat to the sleeving, which will shrink it in size to about 50% of its original diameter.

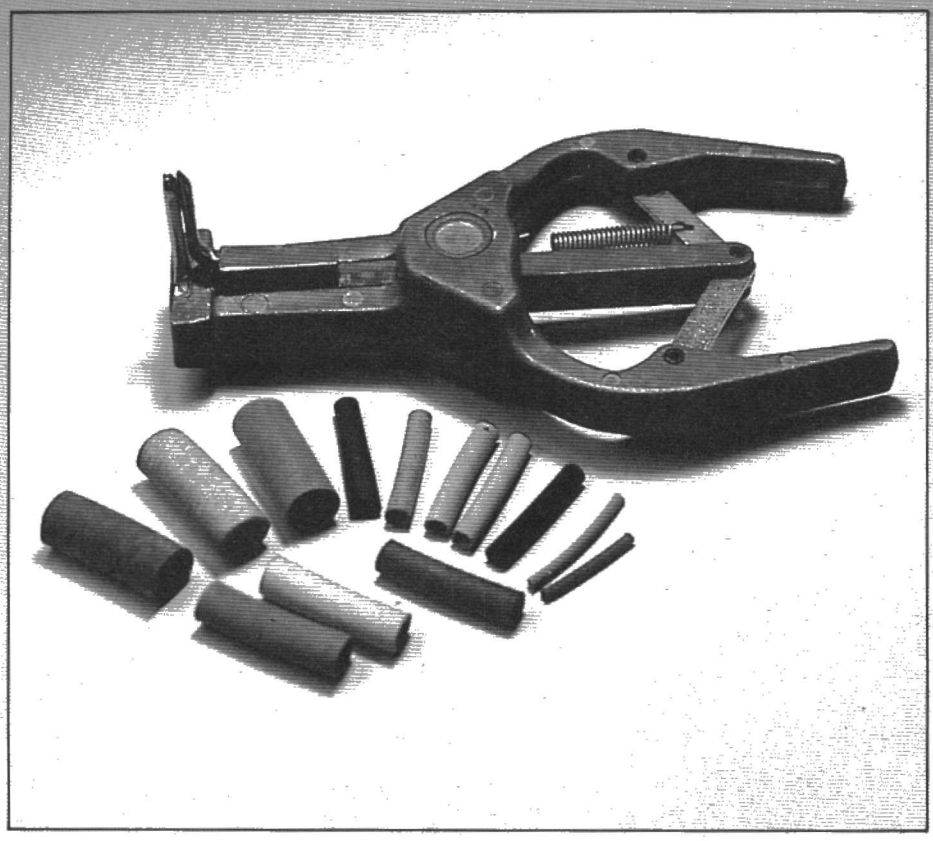
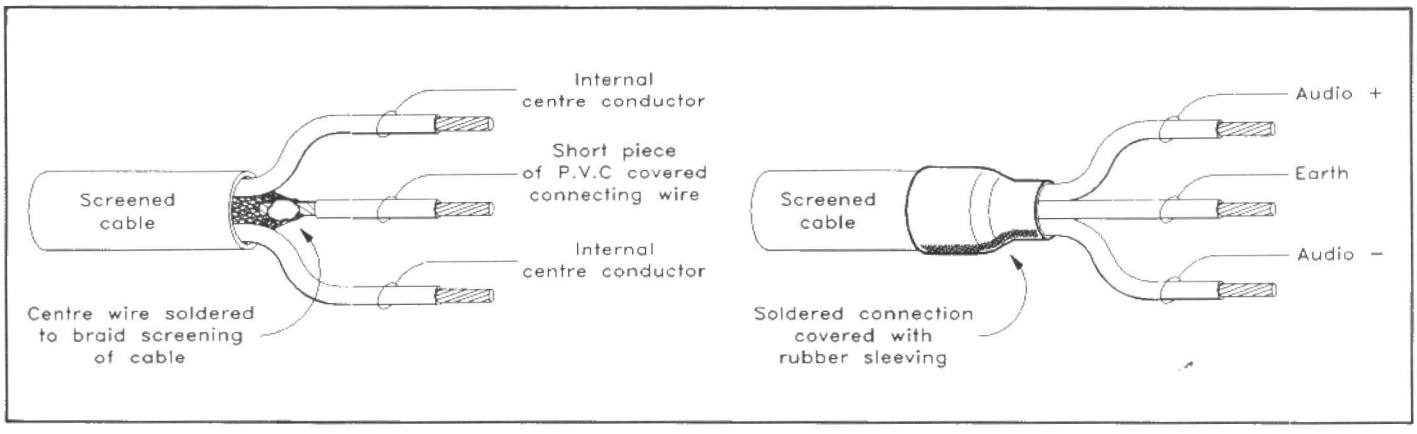
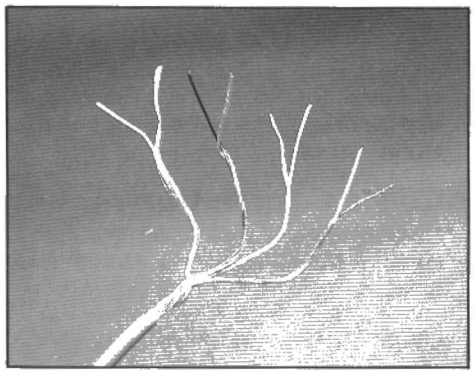
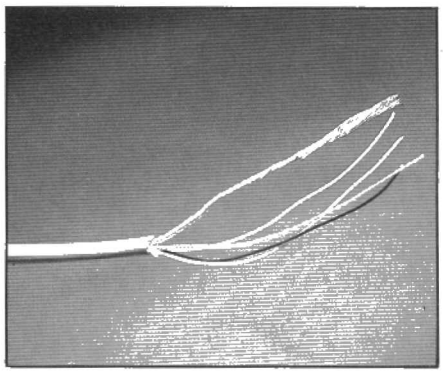


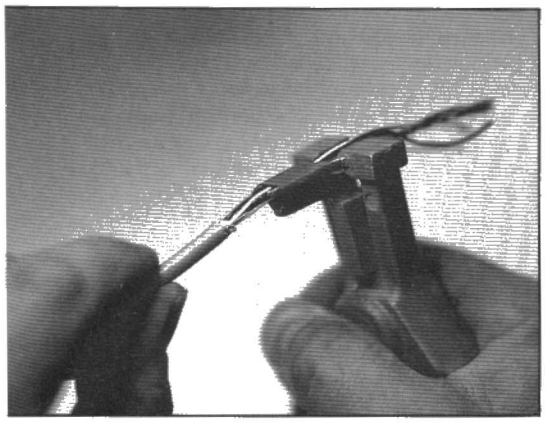
Figure 9. (below) A neat way to finish off cable ends.
Photo 14. (left) A Hellerman tool, shown with a selection of expandable rubber sleeves.

Should you be wiring up something that requires quite a few earth wires to be fixed to the same point, an alternative to the above method is to bend back the twisted earth wire onto the outer sheath of the screened cable, and then solder a finer wire to this earth, bringing this finer wire forward along with the central core. It probably sounds more complicated than it really is, but Figure 9, and the step-by-step illustrations of Photo 15, should make things clearer. Heat-shrinking the cable can be achieved by using a hot-air gun or hair-dryer. However, you may find that certain models of hair-dryer do not generate enough heat for the sleeving to fully shrink, as a temperature of 121°C is required to make it shrink to 50% of its original diameter. You could try using a soldering iron by rolling the bit end over the screening, but be careful, though, as it is easy to roll









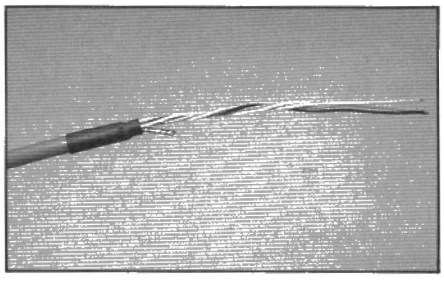


Photo 15. Preparing the four-way screened cable, used to connect the stereo preamp to the front panel controls. Note the use of a Hellerman tool (see text) for the application of expandable sleeving.

the bit off the sleeving, and melt the outer covering of the screened cable.

Using a Hellerman tool (shown in Photo 14) is another way of making neat and tidy cable ends ready for connection. It consists of a three-pronged tool similar in shape to a pair of pliers. You first slide a short piece of rubber sleeving over the three prongs, and then squeeze the tool in your hand as you would a pair of pliers. This causes the three prongs to pull apart, thus widening the diameter of the rubber sleeving.

The rubber sleeving is then placed over the cable in question, and as the pressure on the prongs is released, the sleeving is slid off the tool and onto the cable (refer again to Photo 15). The tool is not cheap to buy, and it takes some practice before achieving a smart result. Once mastered, however, it can produce professional-looking work very quickly. Problems encountered with the screens of coaxial cables can be treated in a similar way to those encountered using heat-shrink sleeving.

Getting Down to Nuts and Bolts!

When the time comes to fasten all the bits and pieces of your project together, don't be tempted to raid the 'odd nuts and bolts' tin sitting on a shelf in your garage. Your project will look much nicer with a carefully selected range of new and shiny nuts, screws and washers. Maplin sell an extensive range, so there is no excuse for not doing it properly!

In an ideal world, it would be nice to have, say, ten or twenty nuts and bolts of every size and length. However, in quantities such as these they don't come cheap, and so it is better to have an initial stock of one nut and bolt of every size. This will enable you to try out any permutation of fixing you require, *before* ordering the prerequisite amount of hardware. This can be useful where details of bolt sizes (for the fitting of components) are not given when constructing an article from a magazine.

It is far easier to see which of a range of bolts fits best into a hole of given diameter, rather than striving to measure the hole accurately. Of course, it does help that the bolts in your possession are marked accordingly with their correct sizes.

Bolts can have panel, round or countersunk heads. Some components require countersunk bolts, so check carefully if this is the case. Don't neglect the fitting of washers; use shakeproof ones if your project is subjected to any mechanical vibration. Using a nut sealant to prevent any nuts and bolts from becoming loose is also good practice. Bottles of sealant can be obtained from model shops – an alternative is to use a small tin of clear varnish and a fine paint brush. Do not use over-length bolts if you wish to give your project a smart appearance. If you cannot find a bolt which will finish flush with a nut, cut off the excess and file the bolt down afterwards.

Solder Tags

These are used to earth various parts of circuitry to a chassis. To enable good electrical contact to take place, make sure that a chassis is clean around the area of fixing. On our 'BENCHMASTER' project, make sure that the area around the mains socket bolt area is bare to the metal – there is a solder tag used here to earth our project via the mains supply. Don't be tempted to take short cuts with the cleaning and fixing of earth tags – they could be your lifeline to longevity, should a serious fault ever develop on your project.

Grommets

Whenever cables need to pass through a hole (particularly one cut in metal!), it is always good practice to use a grommet. Many types are produced, the simplest of which is no more than a circle of rubber. Others include: strain relief grommets, which eliminate the need of a cable clamp; cable seal grommets, which provide a seal around the cable as it passes through a hole; and the flexible grommet strip, which can be used on extra large holes or those of an unusual shape. There are also a variety of cable exit grommets which have a sleeve fitted. These offer an attractive alternative to the normal type, and give extra strain relief to the cable in question. Should you be re-using a box for your project, you may find holes in it that are no longer required. These can be filled in by blanking grommets.

Next month, we will be taking a closer look at the large variety of controls that we have at our disposal, and how to put them to their best advantage when designing a project. In addition, we will discuss how to improve on the visual appearance of a circuit made up on Veroboard. Until then, go slowly with constructing your project, for time reaps its rewards!

CLASSIFIED

If you would like to place an advertisement in this section, here's your chance to tell our 31,125 readers what you want to buy or sell, or tell them about your club's activities – absolutely free of charge. We will publish as many advertisements as we have space for. To give a fair share of the limited space, we will print 30 words free of charge. Thereafter the charge is 10p per word. Please note that only private individuals will be permitted to advertise. Commercial or trade advertising is strictly prohibited.

Please print all advertisements in bold capital letters. Reference Boxes are available at £1.50 each. Please send replies to address below quoting Reference Box Letters. Please send your advertisement with any payment necessary to: Classifieds, Maplin Mag., P.O. Box 3, Rayleigh, Essex SS6 8LR.

MUSICAL

SELECTION OF very high quality audio interconnect cables with professional type gold phono plugs and High Purity Oxygen Free Copper cable, £17 – £30. Tel: Steve, (0295) 265498 after 6pm.

WANTED

IMPOVERISHED COLLECTOR of vintage wireless sets would like to hear from similar persons who have surplus equipment. Tel: (0253) 811106 between 6pm and 7pm (Blackpool).

TEXAS INSTRUMENTS TI-59 calculator and PC100C print cradle – service information wanted for either/both. Tel: Peter, (081) 668 9920.

WANTED URGENTLY, anything on 'Dragon 32', manuals, books, magazines, articles on upgrading, modifications, servicing, programming, etc. Also joysticks, disk drives, hardware, spares. Send list to Mr. O. E. Ford, 6 Victoria Street, Creswell, Nr. Workshop, Notts, S80 4AT.

VARIOUS

500VA TOROIDAL TRANSFORMER YK23A, and 2 × 10,000μF 63V audio grade capacitors FA18U, worth almost £60. Will take £30. All new. Mr. Mears, 22 Carrlane, Glasshoughton, Castleford, WF10 4PL.

SCANNERS BEARCAT 210, range 32–50, 146–174, 420–510MHz, £120 o.n.o. Belcom AMR 217B. Fitted crystals, marine channels 0, 6, 8, 9, 10, 11, 12, 26, 27, 67, 73. Capacity for further 5 channels, £60 o.n.o. Both mains/12V DC. Tel: (0476) 860421 (Grantham).

UV LIGHT EXPOSURE UNIT (Maplin XY10L). As new, hardly used, £25. Tel: (0252) 625010.

MANUALS WITH INSTRUCTIONS and circuit diagrams for Telequipment oscilloscopes D31, D67, D54, D52, and Phillips PM3110, plus have available manuals for various test equipment, £5 each. Tel: (0227) 272581.

TEN GANDALF MODEM boards. Ideal to de-solder for spare parts, over 200 components per board. Including more than 50 ICs. Each board is worth over £70, sell for only £15 each including postage. Write to: Colin Piggot, 204 Lamond Drive, St. Andrews, Fife, KY16 8RR.

MAPLIN MAGAZINES from Issue 1 to date. All in excellent condition: £39 incl. carriage. Tel: Peter, (081) 668 9920.

EX PHILIPS ROTARY variable transformers, 10A single phase, £35 plus P+P. Tel: (0530) 831150.

UV LIGHTBOX (MEGA) working, 9 × 6·25in., excellent condition, hardly used. Cost £64, will accept £39. Tel: (0553) 763383 (Kings Lynn).

GIANT CLEAROUT! Long list of unused components including ICs, capacitors, resistors, some in large quantities. All at bargain prices. Send S.A.E. for list. M. J. Dean, Blenheim, Walton Lane, Bosham, Chichester, West Sussex, PO18 8QF.

SILLY PRICES 128 drawers TTL ICs, £100; 96 drawers resistors/diodes/transistors, £30; 64 drawers capacitors, connectors, etc., £30. 20MHz dual trace scope £150. Power sig. gen. £50. Thurlby bench PSU, £50. Box of PLBs etc. £50. Books plus All above plus much more FREE, £500. Tel: (0638) 750661 after 7pm for details.

4800 SYNTH KIT, Acorn Atom 12K, Atari 800, Synthesiser 80–160MHz, Commodore 8010 modems, HP2602A printer ribbons, Swiss electro-mechanical pulse counters, valves, valve voltmeter, much more. M. E. Walden, 11 Chiltern Close, Duston, Northampton, NN5 6AX.

SATELLITE EQUIPMENT FOR SALE! 16-memory Connexions positioner with 18 in. screw jack (suitable for 1·5m or 1·8m dishes!). Easy to use, in good condition, £60 plus £10 postage. NEC positioner (suitable for use with pulse-feedback actuator), 80 storable positions. In excellent condition. £45 plus £5 postage. Salora 5902 stereo satellite receiver (as recommended by 'What Satellite'), supplied with Memorex universal remote, £85 plus £5 postage. Other satellite/VCR goodies also available. Tel: Martin, (0702) 346003 after 7pm for more details.

COMPUTERS

ATARI 520 STE with 20 games, joystick, mouse, mouse mat, disc box. All boxed, only £220 o.n.o. Tel: Steve, (0483) 421268 evenings (Guildford area).

BBC 1 ELECTRON software on disk or cassette. All original and very cheap. For list send S.A.E. to: C. Roberts, 210 Hern Road, Ramsey, St. Marys, Cambridgeshire PE17 1TB.

ATTENTION ALL 6502 PROGRAMMERS. Write fast, efficient and compact M/C programs easily using my Assembly Generating Compiler. Its own expandable language implements loop structures, conditional tests, string handling, I/O, integer math etc. in 65XX machine code. Complete package runs on C64; source listings can be made available for conversion to another machine. S.A.E. for more details to Level 3, Aurora, Church Road, Basildon, Essex, SS15 5SL.

CLUB CORNER

ELECTRONIC ORGAN CONSTRUCTORS SOCIETY 2.30, May 16, St Pancreas Church Hall, Lancing St, near Eustion station, all welcome. Regional meetings. (081) 902 3390. 87 Oakington Manor Drive, Wembley, Middlesex.

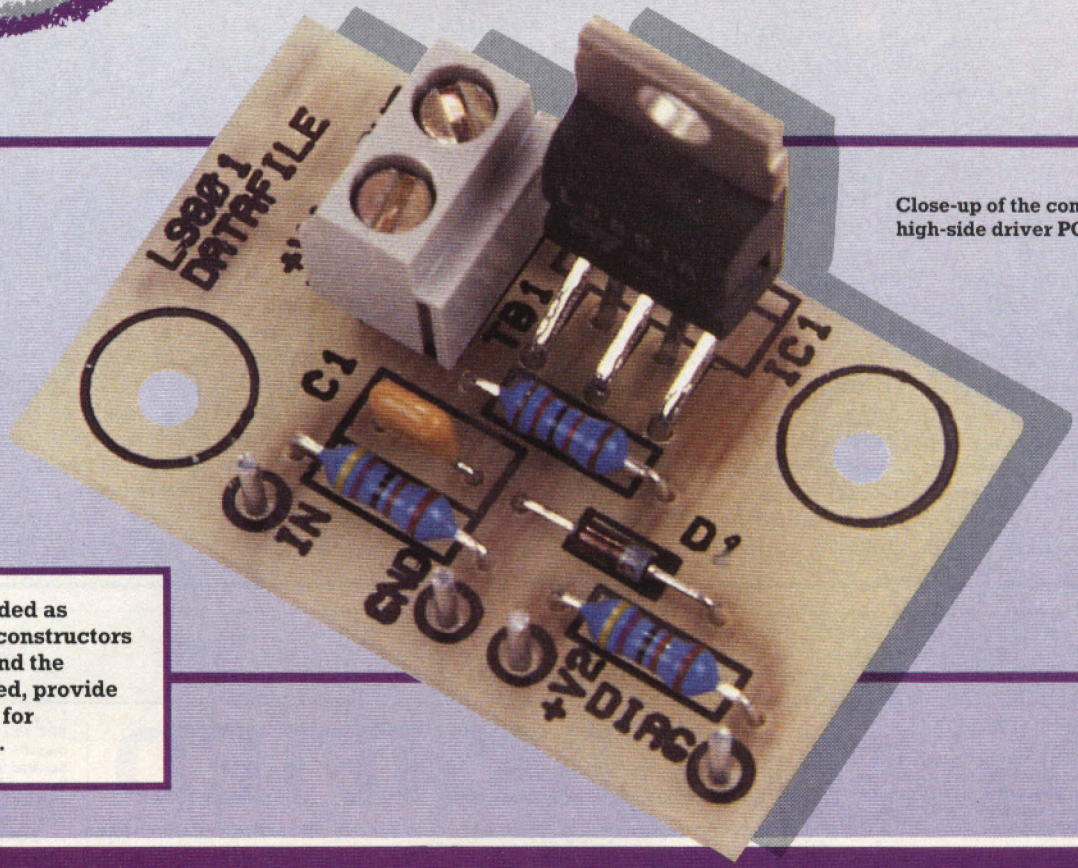
TESUG (The European Satellite User Group) for all satellite TV enthusiasts! Totally independent, TESUG provides the most up-to-date news available (through its monthly 'Footprint' newsletter, and a teletext service on the pan-European 'Super Channel'). It also provides a wide variety of help and information for its members. For further information, contact: Eric W. Wiltsher, TESUG, Rio House, Stafford Close, Ashford, Kent, TN23 2TT, England.

THE BRITISH AMATEUR ELECTRONICS CLUB (founded in 1966), for all interested in electronics. Four newsletters a year, help for members and more! UK subscription £8 a year (Junior members £4, overseas members £13.50). For further details send S.A.E. to: Mr. H. F. Howard, 41 Thingwall Park, Fishponds, Bristol, BS16 2AJ.

ELECTRONIC UK – the electronics club for the enthusiast, now welcoming new members!! News, views, competitions, projects and loads more. For more information, send S.A.E. to: Electronics UK, 48 Lancing Park, Sussex, BN15 8RF.

DATA FILE

L9801 HIGH-SIDE DRIVER



Close-up of the completed high-side driver PCB.

'Data Files' are intended as 'building blocks' for constructors to experiment with and the components suggested, provide a good starting point for further development.

FEATURES

★ 25A Peak Current Capability ★ Low On-Resistance ★ TTL & CMOS Compatible Input ★ Thermal & Over-current Protection ★ Diagnostic Output

APPLICATIONS

★ Automotive Electronics ★ Computer Interfacing ★ Remote Switching ★ Relay Replacement

The integration of electronics with 'traditional' electrical and electromechanical devices, such as motors, relays, solenoids and filament lamps has brought tremendous benefits. However, for the designers of such modern-day equipment, this has brought its own problems. Logic circuits, whether microprocessor controlled or not, do not take kindly to working in the harsh world of 'spikes, surges and high currents'. For moderate current levels, simple buffer transistor circuits can perform admirably, but once currents rise to several amperes, relays or power transistors need to be employed. Relays, which are electromechanical devices, suffer from wear and, in the course of time, reliability problems. Power transistors invariably require driver circuits themselves, and unless circuitry is complex, they only allow efficient switching in the '0V-side' of the load.

The L9801 high-side driver IC is capable of switching both resistive and inductive loads of up to 6A, with a peak current capability of 25A. In use, one side of the load is connected directly to 0V and the other to the positive supply via the L9801; hence the name 'high-side' driver. Typically, automotive applications demand high-side switching – most loads use the vehicle chassis as the 0V connection, this saves on wiring and helps to prevent electrochemical corrosion. The L9801 is

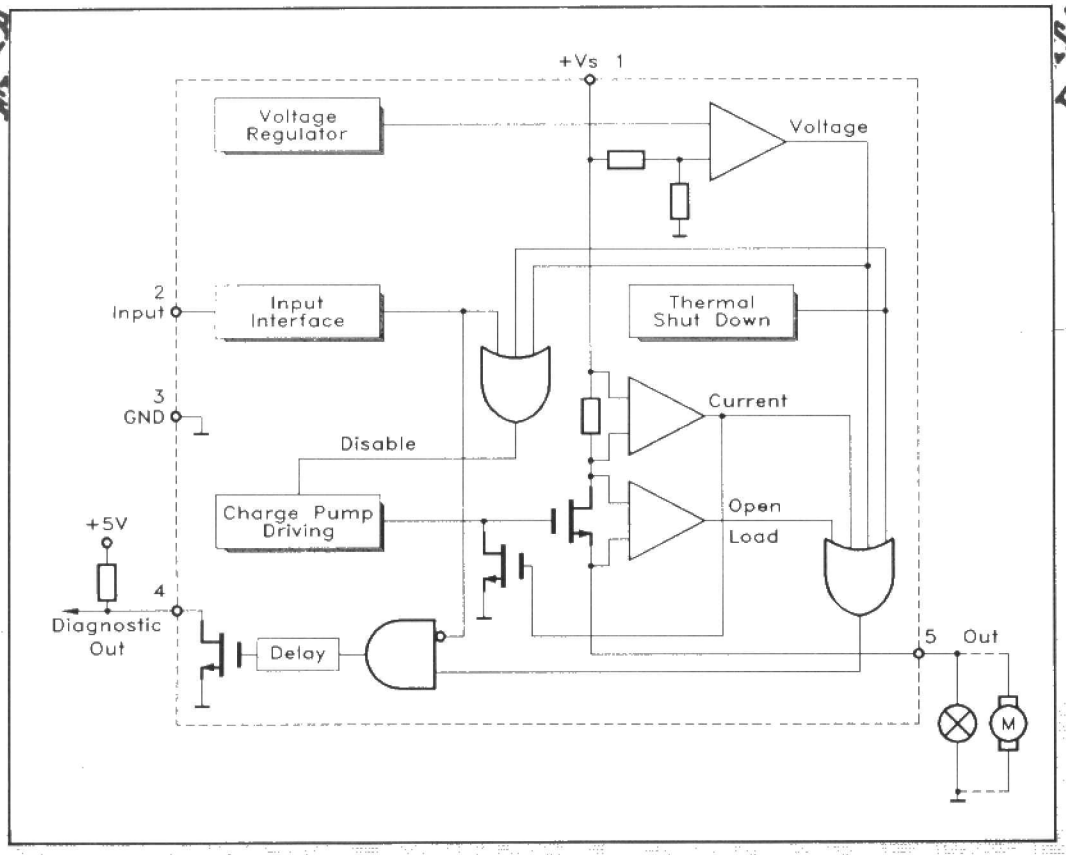


Figure 1. Internal block diagram of the L9801.

particularly suited to driving filament lamps as it limits inrush current; since the initial high current surge at switch-on is a major factor in filament failure, the device effectively increases lamp life.

Figure 1 shows a block diagram of the L9801 and Table 1 gives its electrical characteristics. The input of the device is compatible with TTL and CMOS logic families, thus allowing direct connection to such circuits without further buffering. Apart from operating as an electronic switch, the device protects itself, the power supply and the load from commutation spikes, over voltage, short circuit and over temperature conditions. The device has an on-resistance of 100mΩ (at 25°C), ensuring maximum power transfer to the load and minimum power dissipation within the device.

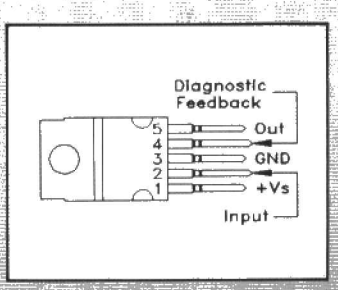


Figure 2. Package outline and pin connections.

A useful feature of the device is a diagnostic output, which indicates an open circuit load, short-circuit output, thermal shutdown and input over-voltage. This may be used to inform the control system of a fault, detected by software diagnostics routine or implemented by hardware, warning indicator LED, etc.

Pin Functions and Descriptions

Figure 2 shows the package outline and pin connections.

1. $+V_S$ – Supply Voltage Input. When the maximum operating voltage of the device is reached (16V), the device switches off protecting itself and the load.

2. INPUT – Control Input. TTL and CMOS compatible, a logic 1 on this pin switches the output on, a logic 0 switches off the charge-pump, the power stage and the diagnostic output to minimise the quiescent current.

3. GND – 0V. This pin must be connected to 0V and should be common to both the supply voltage and control input voltage.

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
V_{op}	Operating Voltage		9		16	V
R_{on}	On Resistance	Input > 2V; T_j = 25°C Input > 2V; Full T Range		0·1	 0·2	Ω Ω
I_{sc}	Short Circuit Current			25		A
I_{DL}	Over Current Detection Level		20			A
I_{OPD}	Open Load Detection Level	Device ON		1·1		A
V_{clamp}	Output Under Voltage Clamping	I_{load} < 6A inductive	−9		−4	V
I_{off}	Off State Supply Current	T_j < 35°C T_j = 85°C			100 300	μA μA
I_{on}	On State Supply Current			4		mA
V_{IL}	Input Low Level				0·8	V
V_{IH}	Input High Level		2·0			V
I_j	Input Current	0 < V_i < 5V			100	μA
I_{LEAKD}	Diagnostic Output Leakage Current	V_{cc} = 5V, Diagnostic Output High			10	μA
V_{SATD}	Diagnostic Output Saturation Voltage	I_{sink} < 3·5mA			0·4	V
t_{Dd}	Diagnostic Delay Time	t_j = 25°C		25		ms
t_{dON}	Output ON Delay Time	t_j = 25°C		4		μs
t_r	Output ON Rise Time	t_j = 25°C		50		μs
t_{dOFF}	Output OFF Delay Time	t_j = 25°C		6·5		μs
t_f	Output OFF Fall Time	t_j = 25°C		2·5		μs

Table 1. ELECTRICAL CHARACTERISTICS: (V_s = 14·4V; −40°C ≤ T_j ≤ 125°C unless otherwise specified)

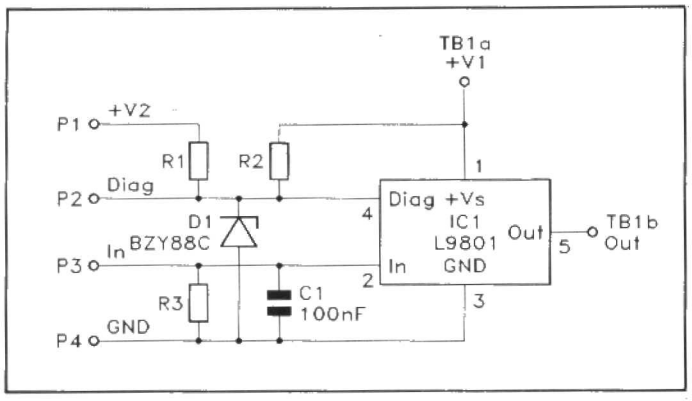


Figure 3. Application circuit.

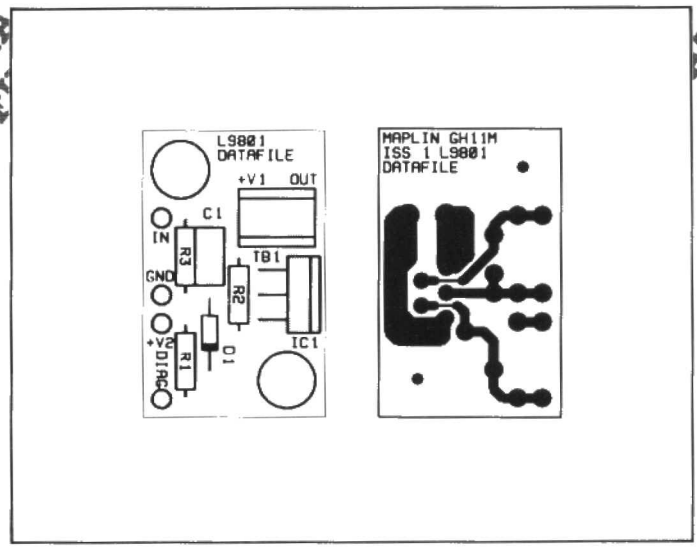


Figure 4. PCB track and legend.

4. DIAGNOSTIC FEEDBACK – Diagnostic Output. The diagnostic circuitry is active when the control input is at logic 1. The output (active low) detects the following fault conditions:

Over-voltage ($+V_S = 16V$)
Thermal Shutdown (junction temperature = 150°C)
Short Circuit ($I_L \geq 20A$)
Open Circuit ($I_L < 1{\cdot}1A$)

To prevent spurious fault indication (turn-on current surge, turn-off voltage spikes, etc.), a 25ms delay is incorporated.

5. OUT – Switched Output. The output is protected against short circuits, current is internally limited to 25A. An external clamp diode is *not* required for inductive loads.

Application Circuit

Figure 3 shows a general purpose application circuit which may be used as a basis for development; a printed circuit board is available to facilitate this, and as such, forms a module to be integrated in a complete system. Options are provided to make the circuit as flexible as possible, however, component values may need to be changed for particular applications. The following component descriptions are given to assist development:

R1 diagnostic output pull-up resistor for use with an off-board supply voltage, i.e. logic circuit +5V supply. Nominal value 4k7Ω for +5V supply, 12kΩ for 12V supply. If an off-board supply is used do not fit R2.

R2 diagnostic output pull-up resistor for use with the on-board supply. Nominal value 12kΩ, 2k2Ω if ZD1 fitted . If the on-board supply is used do not fit R1. See also ZD1 below.

R3 control input pull-down resistor, prevents spurious switching of load if input is left unconnected and allows a low current switch to be used to control the L9801. Nominal value 4k7Ω. If L9801 is being directly driven by TTL or CMOS omit R3.

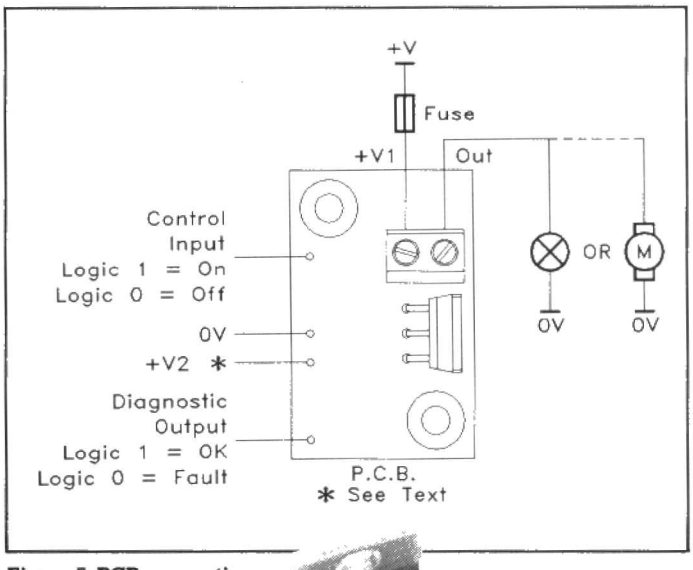
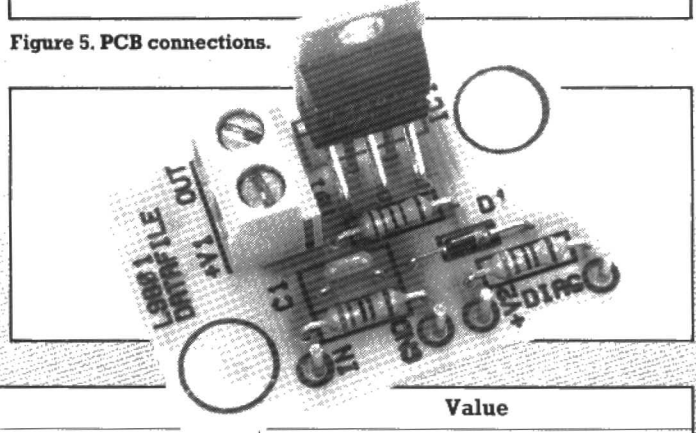


Figure 5. PCB connections.



Symbol	Parameter	Value
V_S	Maximum Forward Voltage Positive Transient Peak Voltage (dump : τ_f fall time constant = 100ms, 5ms $\leq t_{rise} \leq$ 10ms, $R_{source} \geq 0{\cdot}5\Omega$) – Resistive Load – Inductive Load	50Vdc 60V 50V(*)
	Reverse Input Voltage	−0·3Vdc
V_1 V_4 V_5	Input Voltage Pin 2 (to GND) Pin 4 Voltage (to GND) Pin 5 Voltage (to GND)	−0·3V /+ V_s ($V_s < 20V$) −0·3V /+ V_s ($V_s < 20V$) −3V /+ V_s ($V_s < 20V$)
I_1 I_2 I_4 I_5	Pin 1 Current Pin 2 Current (forced) Pin 4 Current (sink) Pin 5 Current	Internally Limited 0·5mA 10mA Internally Limited
P_{TOT} T_J, T_{STG}	Power Dissipation Junction and Storage Temperature Range	Internally Limited −55°C to + 150°C

* due to the negative voltage at the output during the switching off.

Table 2. Absolute maximum ratings.

ZD1 diagnostic output clamp diode, limits diagnostic output voltage to predetermined level. Nominal zener diode voltage 4V7, R2 value 2k2Ω.

C1 decouples the control input and prevents instability.

Figure 4 shows the PCB legend and track to assist component placement. Note, two areas of track are left free from solder resist, this is to allow tinning of the tracks, thus increasing current capacity.

Figure 5 shows connections to the terminal block and the PCB pins. TB1a ($+V_1$) supply for load, TB1b (OUT) output to load. P1 ($+V_2$) off-board pull-up supply, P2 (DIAG) diagnostic output, P3 (IN) control input, P4 (GND) 0V.

Table 2 gives the absolute maximum ratings for the L9801.

Heatsinking

For continuous currents up to 2A heatsinking is generally unnecessary, above this level a heatsink should be used, see Table 3. The tab of the L9801 is at 0V potential and it is likely that in most instances an insulating mounting kit will be unnecessary, however, heat transfer compound should be used. The quoted thermal resistance of the device (junction to case) is 1·5°C/W.

Load current	Heatsink thermal resistance	Suggested Maplin type
≤2A	No heatsink required	
≤3A	≥22°C/W	FL58N
≤4A	≥9·9°C/W	FG55K
≤6A	≥4·2°C/W	FG51F

Table 3. Suggested heatsinking for L9801.

It should also be borne in mind that the on-resistance will increase with temperature. For automotive applications assume R_{ON} = 200mΩ and T_{AMB} = 70°C.

L9801 HIGH-SIDE DRIVER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film			
R1,3	4k7	2	(M4K7)
R1,2	12k	2	(M12K)
R2	2k2	1	(M2K2)
CAPACITOR			
C1	Monores 100nF	1	(RA49D)
SEMICONDUCTORS			
D1	BZY88C4V7/BZX55C4V7	1	(QH06G)
IC1	L9801	1	(UM55K)
MISCELLANEOUS			
TB1	2-way PC terminal	1	(JY92A)
P1-4	Pins 2145	1 Pkt	(FL24B)
	PCB	1	(GH11M)
	Instruction Leaflet	1	(XT66W)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)		
Slotted Heatsink	If req	(FL58N)
Powerfin Plastic	If req	(FG55K)
Powerfin TO3	If req	(FG51F)

The Maplin 'Get-You-Working' Service is not available for this project.

The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.

Order As LT02C (L9801 Hi-Side Driver) Price £7.95.

Please note: where 'package' quantities are stated in the Parts List (e.g. packet, strip, reel, etc.) the exact quantity required to build the project will be supplied in the kit.

The following new item (which is included in the kit) is also available separately, but is not shown in the 1992 Maplin Catalogue.

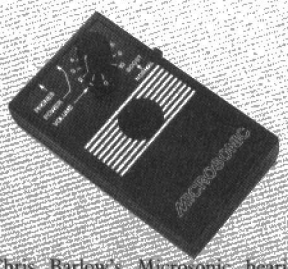
L9801 PCB **Order As GH11M Price £1.75.**

In next month's super issue of 'Electronics – the Maplin Magazine', there are some really great projects and features for you to get your teeth into! The July issue is on sale 5th June 1992, available from Maplin's regional stores and newsagents country-wide, and of course by subscription (see page 54 for details). To whet your appetite, here's just a taster of *some* of the goodies on offer:

SPACE SHUTTLE

Chris Yates' feature on Electronics in Aviation takes a look at the Space Shuttle. Watch this 'space' for some stunning photographs!

MICROSONIC AUDIO BOOSTER



Chris Barlow's Microsonic hearing booster offers significant advantages over (expensive) commercially available units. Intended for the partially deaf, or just those who want to 'hear everything', this project features a VOGAD (Voice-Operated Gain Adjusting Device) to keep the output level safely constant.

FUNTRONICS: DECISION MAKER

Apart from being ideal for the average politician, this beginners' kit will also suit the younger person; as with all Funtronics projects, no soldering is required!

LAPTOP/NOTEBOOK PCs

Frank Booty examines the current portable PC market, and gazes into his crystal ball to see what lies ahead. Astonishing to think that some of these tiny machines are *more* powerful than the best desktop machines of only a few years ago!

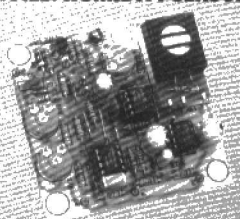
VIDEO PROCESSING SYSTEMS

J. A. Rowan discusses video recording, timebase correction and vision mixing techniques.

100W STEREO CAR AMPLIFIER

If you're a music fan and you 'live' in your car, or you're simply somebody who wants to 'beef up' the sound of a somewhat ineffectual radio/cassette player, then you'll love this! The unit works from line or speaker-level inputs, and can run off either a 12V, or a 24V (ideal for truckers!) battery system.

DATA FILE: HUMIDITY SENSOR



Covers the H14 and H14DL humidity sensors. These modern devices are ideal for replacing the ageing mechanical sensors used in humidity control systems.

SEQUENTIAL LOGIC

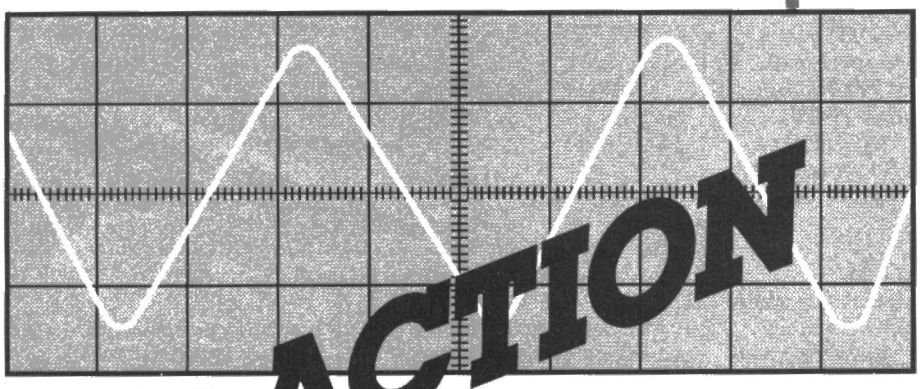
Graham Dixey deals with interfacing counters and registers to displays and other devices.

Plus of course there's all the usual features for you to enjoy!

'ELECTRONICS – THE MAPLIN MAGAZINE'

BRITAIN'S BEST SELLING ELECTRONICS MAGAZINE

The Oscilloscope in ACTION



Part 2 by Graham Dixey, C.Eng., M.I.E.E.

Signals input to the Y amplifiers of the CRO are amplified (or attenuated) in wide-band, linear amplifiers so as to present an undistorted display on screen. The amplifiers themselves have accurately calibrated controls, with markings in volts/division, which then provide a known relationship to the display magnitude. This facility allows the CRO to be used to measure the amplitudes of voltages and currents with a reasonable degree of accuracy. In a similar way, the duration of the X sweep is determined by a switched frequency timebase, with time/division calibrations that allow the user to measure time intervals, whether they be the full periodic time of a recurring waveform, or merely the time between two specific events. The measurement of voltage (and current) will be the subject of this article.

Initial Setting Up

Prior to attempting any measurement using the CRO, the trace must be adjusted correctly for brightness and focus. Since CRO measurements, rather like those on graphs, rely for their accuracy upon observing the position of a line, it follows that this line should be as sharp and clear as possible. This does not mean turning the brightness up until the screen glows brightly – quite the opposite! The sharpest trace is obtained with *minimal* brightness. Have the brightness control set no higher than that which will give a clearly visible trace, then adjust the focus control for the sharpest possible line.

Measurement of Amplitude

Measurement of the amplitude of a signal makes use of the calibrated Y amplifier gain controls in conjunction with a 'graticule'. This is the name given to the plastic overlay to the screen which has a chequerboard, square pattern of lines with intermediate markings along the major X and Y axes. Conventionally, the squares are considered, quite often, as being of 1cm in size, though the actual dimension is of no importance. Thus, one might find that the Y gain controls of one CRO are marked in volts/cm, while those for another CRO are marked in volts/div. Whatever their size, the reason for the squared marking is to allow the X and Y values of any given waveform to be expressed in a linear fashion, which can then be translated into the appropriate physical units by means of the calibrations.

Measurement of DC

Although it is hardly likely that anyone would actually choose a CRO to measure the direct voltage in a circuit – a multimeter being the more obvious choice – the measurement of a DC potential may sometimes be made in relation to the measurement of a related signal voltage. For example, it is quite common to find that an alternating signal 'sits upon' a DC voltage (as at the collector of a transistor, for instance), and it may be of interest to know both the signal's magnitude and DC level at that point, at the same time (Figure 1). This could tell us whether the standing conditions in the circuit are correct or not. Measurement of the AC signal only, would not yield this information.

An example is the output stage of a power amplifier (Figure 2), where the signal output is derived from the junction of the push-pull output transistors. This point is known as the 'mid-point' and it has to be preset to a value equal to half the supply voltage value, in order to be able to accommodate both positive and negative swings of the signal equally. If this point is not correctly set, then distortion will occur on one peak before it does so on the other; this is because, if the mid-point is too high, the positive peak will reach the supply potential too early, while if it is set too low, the same thing will happen for the 0V line. The CRO can detect this condition and allow the mid-point to be set up properly by noting when distortion begins on both signal peaks equally.

Setting Up for DC Measurements

To make use of the DC facility, it must be selected at the Y amplifier input. On some models of CRO there is a three-way switch marked something like 'AC/GND/DC'. With this switch at the centre position, the input of the Y amplifier is

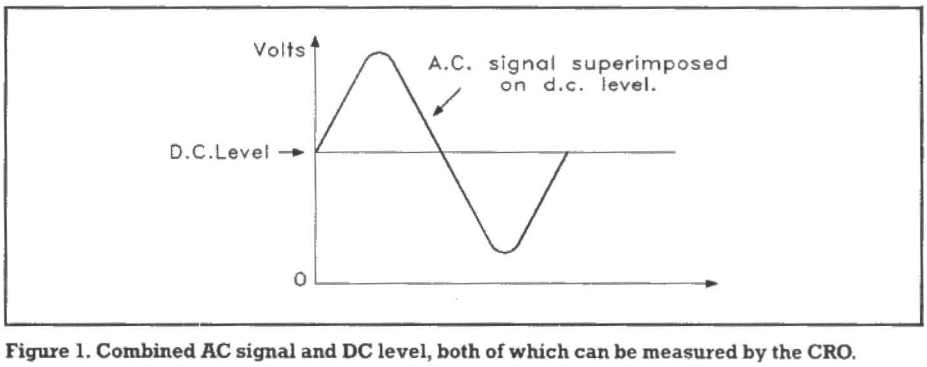


Figure 1. Combined AC signal and DC level, both of which can be measured by the CRO.

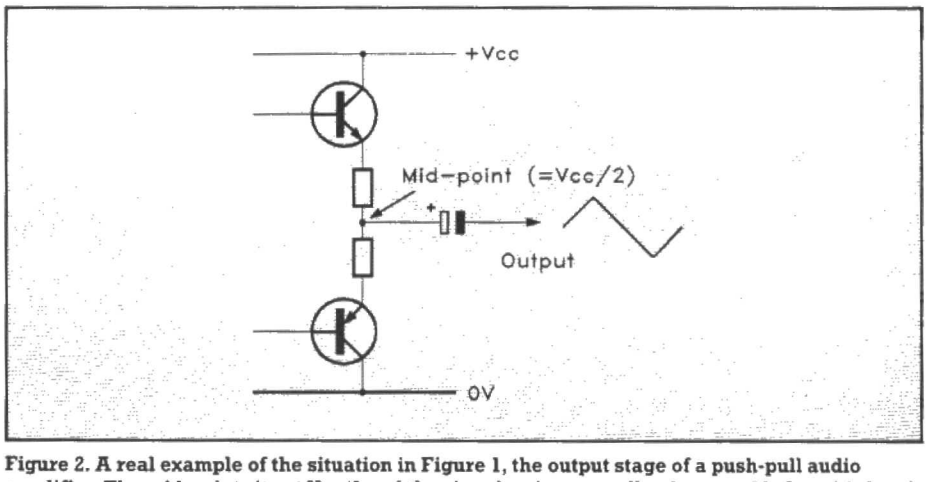


Figure 2. A real example of the situation in Figure 1, the output stage of a push-pull audio amplifier. The mid-point sits at $V_{CC}/2$ and the signal swings equally above and below this level.

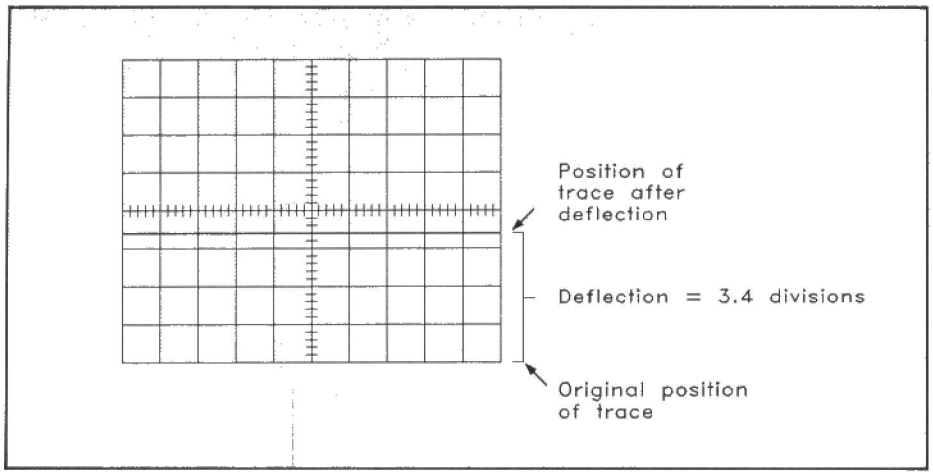


Figure 3. Measurement of DC level by Y deflection.

grounded, that is referred directly to 'zero volts'. While this condition is selected, the Y shift control can be used to position the trace correctly in the vertical direction. What do we mean by correct in this sense?

We mean that it is positioned so that any voltage within the range likely to be met (usually lying between 0V and the supply value) will produce an observable and measurable deflection, without actually driving the trace off the screen. If the voltages to be measured are all positive, then it makes sense to position the trace at the bottom of the graticule. The Y gain must then be set to a sensible value, derived as follows:

Suppose that the measurement is being made in a circuit where the value measured will lie in the range 0 to +12V. If the overall height of the graticule is eight divisions, then if a Y amplifier gain of 1V/div. is selected this will clearly be inadequate, because the full screen height will correspond to no more than 8V. It will be necessary to set the Y gain to the next available calibration, usually 2V/div. This will then allow the screen to accommodate a range from 0V to +16V, more than adequate.

Having positioned the trace and selected the Y gain, the 'AC/GND/DC' switch previously described should be set to DC input. This bypasses the normal input coupling capacitor and allows the input signal to be directly coupled through to the Y amplifier. The trace will be deflected upwards, and the number of divisions that it is deflected, allows the DC level to be calculated. In the diagram of Figure 3, the trace has moved up by slightly less than 3·5 divisions, say it is estimated at 3·4 divisions. The DC level is given by:

DC level = deflection in divisions × volts/division.
= 3·4 × 2,
= 6·8V.

A limitation of the DC input occurs where the signal itself, that is the AC part of the combined voltages, is small in amplitude in comparison with the value of the DC level on which it sits. If the Y gain is set correctly to accommodate the DC value, the signal is too small either to be observed properly or to be measured. On the other hand, if the Y gain is set to a value that suits the small amplitude of the signal, the large DC value will drive the trace off screen. The only way to measure small values of AC signal is to select the AC input mode. This switches in a large coupling capacitor (perhaps the term DC blocking capacitor would be better) that isolates the Y amplifier input from any DC present in the signal. A suitable value of Y gain can then be set without the DC level of the signal having any effect.

Measurement of AC

Before we consider how to make the actual measurement, consider the fact that the value of an alternating voltage or current is less readily defined than that of a DC quantity. The usual way of expressing the value of AC is by using one of four alternatives: peak-to-peak, peak, average and RMS (Root Mean Squared). The order given here is not meant to express any particular priority or preference, but it might be seen to express the ease with which the CRO can be used to measure each of them, with peak-to-peak as the easiest and RMS as the most difficult. In fact, the CRO cannot measure either average or RMS values directly, the value is derived by means of calculations based on the measurement. Let us take each of these in turn.

Measuring Peak-to-Peak Value

The peak-to-peak value of a waveform is the value of a voltage measured directly between the positive and negative peaks. This is illustrated in Figure 4.

The controls associated with this measurement are the Y gain control, the time base (X) control, and the X and Y shift controls. The Y gain is selected to produce the largest size display without either peak going off screen. The timebase is set to display a few cycles only (or merely one cycle – it isn't critical). The X and Y shift controls are adjusted so that a positive peak, say, coincides with a convenient horizontal line on the graticule (see Figure 5(a)); for the moment it doesn't matter where the negative peak is. The vertical displacement of the positive peak with respect to the major X axis is then noted. In this case it is 3 divisions.

Without touching the Y shift control, the X shift control is rotated until the negative peak is accurately positioned on the Y major axis (Figure 5(b)). The vertical displacement of this peak relative to the major X axis is noted.

In this case, it is 2·6 divisions.

The peak-to-peak height of the waveform is the sum of these two measurements.

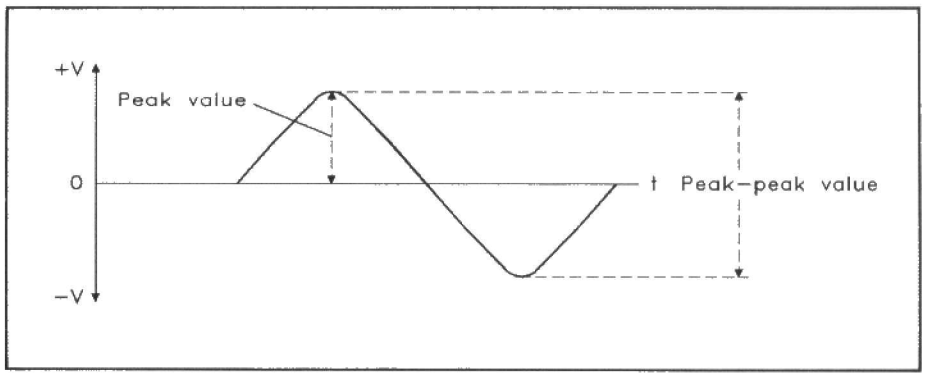


Figure 4. Peak-to-peak and peak values of a sinewave.

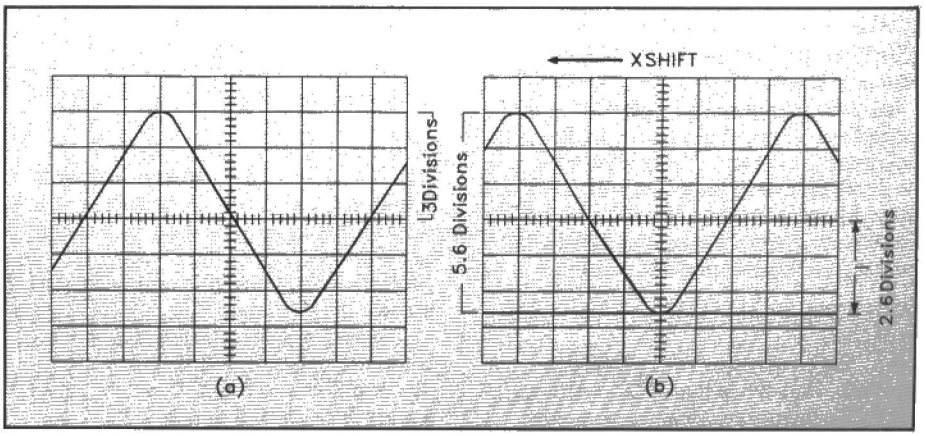


Figure 5. Measuring peak-to-peak value: (a), positive peak aligned with suitable mark; (b), waveform 'X shifted' to position negative peak. Total vertical deflection is then read off.

In this case, it is equal to 3 + 2·6 = 5·6 divisions.

To convert this to voltage, simply multiply this number of divisions by the Y gain setting. Assume that this has been set at 200mV/division.

Then the peak-to-peak voltage = 5·6 × 200,
= 1120mV,
= 1·12V

Measuring Peak Value

The peak value is also defined in Figure 4 and is the voltage value measured directly between the base line of the waveform and its peak. Since the position of this baseline is not readily identified, it is better to measure the peak-to-peak value first and merely divide it by two.

In this case, the peak value = 1·12V/2 = 0·56V.

Measuring Average Value

Taken over a full cycle, the average value of a sinewave is, of course, zero. There is just as much waveform above the baseline as there is below it. Thus, when we talk about the average value we are usually referring to the average height of one half-cycle, measured over a half-cycle. On this basis, the average value of a sinewave is given by:

Average value of a sinewave = 0·637 × peak value.

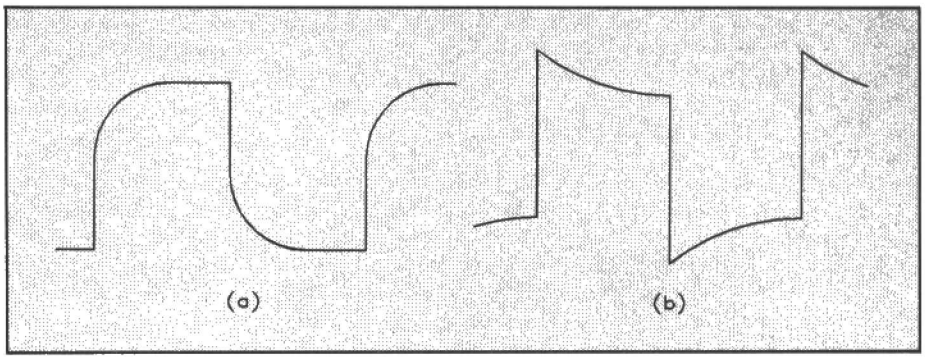


Figure 7. Distortion possible in square-waves: (a), by integration; (b), by differentiation.

value of a waveform is rarely of much interest anyway.

Waveforms other than Sinewaves

The measurement of peak-to-peak and peak values is readily applied to other waveforms, as in the case of the ripple voltage across a reservoir capacitor (Figure 6(a)), or of a pulse or square wave, these being two other commonly encountered waveforms (Figure 6(b)).

In the case of the latter, the waveform may be degraded from the ideal by RC time-constants that are encountered in the transmission path. Depending upon the nature of these, the waveform will appear as in Figure 7(a) and (b). The waveforms are said to have been 'integrated' and 'differentiated' respectively. The degree of degradation of waveform (a) can be measured by

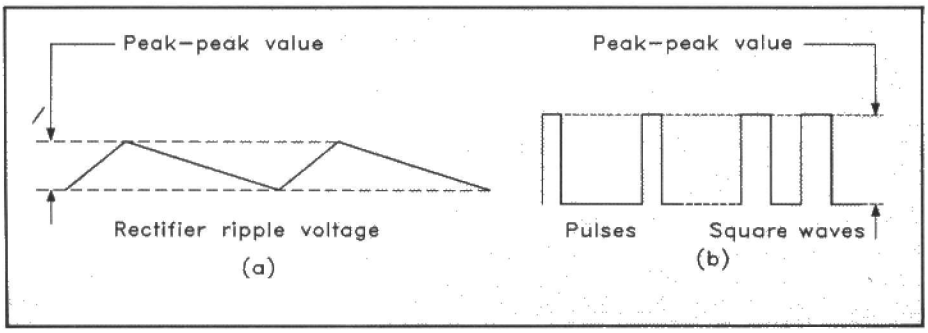


Figure 6. Examples of other waveforms where peak value is important: (a), rectifier ripple voltage; (b), pulses and square-waves.

Clearly, all we have to do is multiply the peak value previously obtained by this figure of 0·637.
In this case, the average value = 0·637 × 0·56,
= 0·357V.

Measuring RMS Value

The RMS value of a sinewave is the way in which the alternating quantity is related to the amount of work that it is capable of doing, compared with the equivalent amount of DC. This is found to be so when a value equal to 0·707 times the peak value is taken. This value of 0·707 is not arrived at empirically, of course, but derived mathematically.

In this case, the RMS value = 0·707 × 0·56,
= 0·396V.

If the above proves anything it is probably that, while the CRO is certainly useful for measuring peak-to-peak and peak values, it is less than ideal for measuring RMS values. The average determining the rise and fall times (which, being time measurements, will be discussed in the next article), while the degradation of waveform (b) can be determined by measuring the 'sag'. This is the vertical difference in voltage between the two levels, A and B, indicated in Figure 7(b). This is carried out by using the X and Y shift controls to position the two levels, one at a time, against the major Y axis, measuring the vertical distance between them, and converting this to a voltage in the usual way. The greater the sag, the worse the waveform. This is an effect that usually occurs at low frequencies, and it is one of the ways in which the bandwidth performance of an audio amplifier can be assessed.

If a square wave at some low frequency, say 40 to 50Hz, is fed into the amplifier and the CRO is connected across the output, the waveform at the output can be compared with a perfect square-wave. If it shows a lot of sag, this implies that the low frequency response (its bass response) is none too hot. If instead a high frequency square-wave is fed in at, say, 10kHz, this again can be compared with the ideal square-wave and the presence of exponential leading and trailing edges is an indication of a lack of good high frequency performance.

The CRO Probe

A useful and inexpensive accessory to have with a CRO is the probe. This is a passive device, containing a (typically 9MΩ) resistor which, together with the standard 1MΩ input impedance of the CRO, forms a 10:1 resistive attenuator, with a compensating capacitor in the form of a trimmer. The reason for its inclusion can be explained by reference to Figure 8. This shows that, when the probe is connected to the CRO Y input, there are actually three identifiable capacitances. One of these is the trimmer in the probe, while the other two are the capacitance of the screened cable and the input capacitance of the CRO. The latter has a typical value of about 40pF, and the cable capacitance depends upon the length of the cable, and this applies equally to any coax. cable, not just one with a probe attached. The capacitance of this cable may be in the order of 100pF/metre, so one metre of cable will contribute an extra 100pF of capacitance in parallel with the input capacitance of the CRO itself, leading to a total effective input capacitance of 140pF, in this example. The reactance of this 140pF shunts the 1MΩ input resistance, leading to a marked lack of response at high frequencies. This has two effects:

(i) The response of the CRO to sinewaves of high frequency is reduced, leading to the impression that the signal is of a lower amplitude than it really is.
(ii) The response of the CRO to square-waves of medium to high frequency is also reduced, producing distortion in the displayed square-wave of the form shown in Figure 7(a).

The use of a 10:1 passive probe reduces these effects dramatically, and it is always worthwhile to use one as standard practice. The price that one pays for this is a 10:1 loss in Y sensitivity, but it is only while examining the smallest signals, those of a few millivolts in amplitude, that this is likely to matter.

Because the key to using a probe lies in the compensating capacitance that is connected across its 9MΩ attenuating resistor. This combination produces a

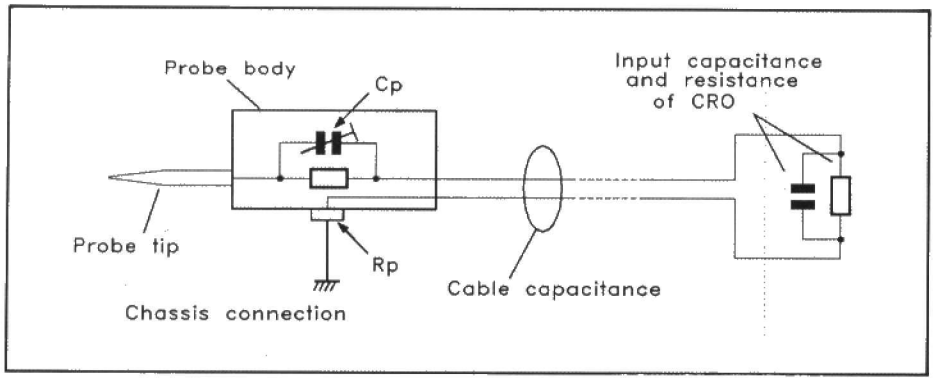


Figure 8. The CRO probe allows the cable and input capacitances of the CRO to be 'trimmed out'.

time constant of Rp × Cp. Let us put some figures to this. Assume that the trimmer has a range of 3 to 30pF. This gives a time constant that is variable between the limits of,

At the lower end: 9MΩ × 3pF = 27μs

At the upper end: 9MΩ × 30pF = 270μs.

Now consider the time constant for the input of the CRO, including the cable.

This equals: 1MΩ × 140pF = 140μs.

What is the significance of these figures? The answer is that the compensation will be correct when the time constant of the probe components is the *same* as the time constant of the CRO input. The latter has been seen to be 140μs (with cable) in this example. The probe can be adjusted to have a time constant in the range 27 to 270μs, which covers the value of 140μs nicely. What we must do is adjust the probe trimmer to obtain this value.

How do we do this? Well first we need a source of good quality square-waves. Most CROs have such an output on their front panel for such calibration purposes. This is connected to the probe input and the resulting display observed once the X and Y controls have been adjusted for the latter to be clear and stable. The trimmer should be adjusted until there is neither sag nor exponential rise and fall. The compensation is then correct.

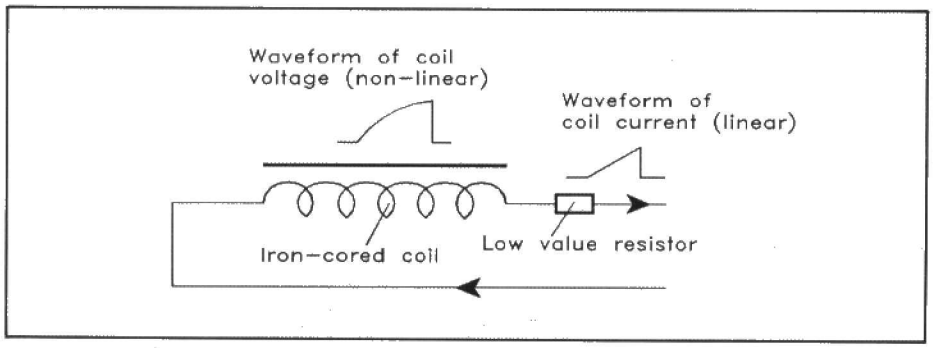


Figure 9. Measurement and display of current waveform using the CRO.

Measurement of Current

The CRO is essentially a voltage operated device, hence it cannot measure a current directly. This is no real problem however, since it is an easy matter to convert a current, of whatever form – DC or some alternating waveform – into a voltage of precisely the same form. All that we need do is pass this current through a linear device so as to produce a directly related voltage drop. The ordinary resistor is such a device. It is connected in series with the current path as shown in Figure 9.

In this example it is required to examine the waveform of current in an iron-cored coil. If the CRO Y input were to be connected directly across the coil, the waveform observed would not be the same as that of the current flowing in the coil. This is because any iron-cored coil is essentially a non-linear device. Thus, if the coil current is a linear waveform, the voltage waveform cannot be. This is particularly true of the scan current in electromagnetically deflected cathode ray tubes. For a linear scan, the current waveform must be a linear sawtooth. This can only be observed by adopting the technique described. Naturally, the value of the resistor chosen should be fairly small so as not to reduce the value of the current markedly. Once displayed, the magnitude of the voltage across this resistor can be measured in the usual way. This can then be converted into current by using Ohm's law: I = V/R.

In the Part 3 of this series next month, we look at measurements related to time.

COMPETITION WINNERS

Capital Radio Competition

The questions and correct answers to the Capital Radio competition which appeared in issue 49 (January) were as follows:

1. Capital FM is the world's most popular commercial music station.
What does FM stand for?
Frequency Modulation

2. What does Capital Gold signify?
The station of Golden Oldies

3. Who is unlikely to be top of the Capital pops?
Kim Basinger

4. Spot the odd one out:
Ken Livingstone

The first lucky winner to be drawn out of ye olde editor's hat was Richard Aldred of West Sussex, who wins a conducted tour for himself and a companion around the Capital Radio emporium.

There are six additional runners-up, who will each receive a Capital Radio T-Shirt. They are:
Brian Kenyon, Ramsbottom, Lancashire; Mr. R. Grainer, Horsham, West Sussex; Mark Cook, Braintree, Essex; Timothy Page, Carshalton Beechey, Surrey; Atul Patel, South Tottenham, London; Daren Ford, Cardiff, South Glamorgan.

BT Museum Competition

The questions and correct answers to the BT Museum competition, which appeared in issue 51 (March) were as follows:

1. Spot the odd one out:
Madonna

2. Which country shared the first international telephone link with London?
France

3. What does 'STD' stand for?
Subscriber Trunk Dialling

4. What was 'Early Bird'?
The first commercial communications satellite

5. What is optical fibre made of?
Glass

Mr. R. Pearce of Olney, Buckinghamshire drawn out of an old cardboard box this time, was the star winner of an expenses paid trip to Goonhilly Satellite Earth Station in Helston, Cornwall.
Second and third prizes of a visit to the BT tower go to Michael Rowles of Neath, West Glamorgan, and R. A. Evans of Winchelsea, West Sussex.

Ideal for beginners – No soldering required.

All You Need to Build Your Own

FUN TRONICS

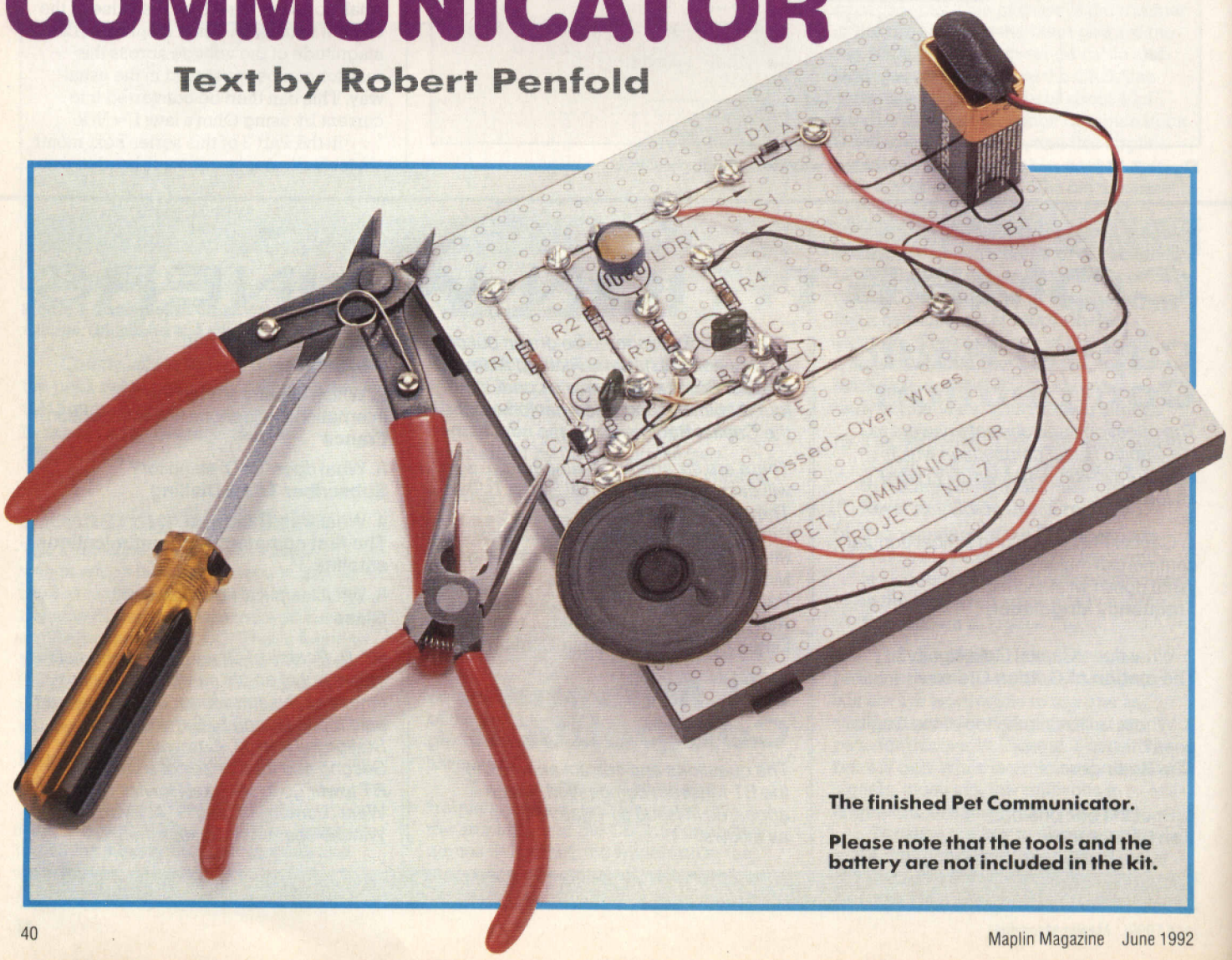
PROJECT No7

PET COMMUNICATOR

Text by Robert Penfold

Probably most of you are familiar with so-called 'dog whistles', which produce a sound of such high pitch that it is inaudible to humans. Dogs can hear much higher pitches than people can manage, and a properly trained 'best friend' will come when a dog whistle is blown. It is not only dogs that can hear these high frequency ('ultrasonic') sounds. A lot of small furry creatures, including cats, mice, and hamsters, can hear these sounds.

The dog whistles that I have chanced upon have been a bit disappointing. They actually produced whistles that could just about be heard by anyone with good hearing. This electronic version is much the same, and anyone with good hearing should be able to hear the highest frequencies that it produces. Therefore, we cannot guarantee that it will reach the pets that other whistles cannot reach! With a simple modification, this project will operate as an alarm – which generates sounds that *all* people can hear.



The finished Pet Communicator.

Please note that the tools and the battery are not included in the kit.

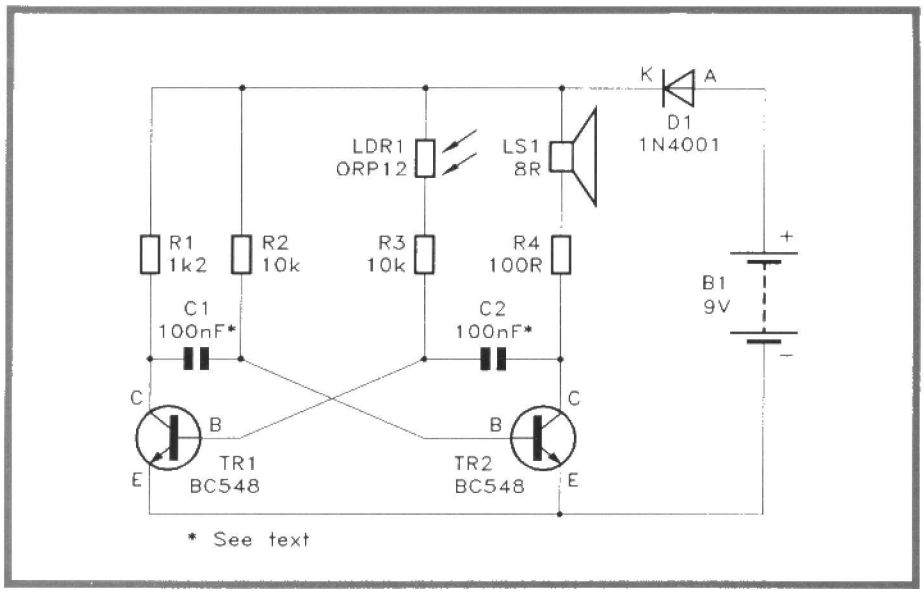


Figure 1. The Pet Communicator circuit diagram. LDR1 is the photocell.

How it Works

The circuit diagram for the Pet Communicator is shown in Figure 1. It may look slightly familiar, as it is the same type of circuit that was used in the 'Flasher' project ('Funtronics' project No. 5, see issue 52 of 'Electronics'). In other words, it is an astable multivibrator, which is a rather grand name for quite a simple circuit. It operates by repeatedly charging and discharging C1 and C2. When C1 is charging C2 is discharging, and vice versa. This process results in TR1 and TR2 switching 'on' and 'off'. When one of these transistors switches on, the other switches off. This type of circuit can sometimes be likened to an electronic 'see-saw'.

The Flasher project worked at a very low frequency, and operated two LEDs. In this circuit the values of C1 and C2 are much smaller, which greatly increases the rate at which they charge and discharge. As a result of this, the circuit operates at a much higher frequency. Instead of switching over every few seconds, it switches over at frequencies which can vary between several hundred, and several thousand, times a second.

Instead of driving an LED from each transistor, a loudspeaker (LS1) is driven from TR2. It turns the pulses of electricity it receives into sound pulses. When initially testing the unit, it is a good idea to use the 100nF capacitors for C1 and C2, so that the sound produced will be well within the human range of hearing. Using the 10nF capacitors, the output frequencies will be some ten times higher. The highest pitches will then be close to the upper frequency limit of human hearing. In fact the highest frequencies might be too high for you to hear them. In general, younger persons have better high frequency hearing than older folk.

One of the resistors in the circuit is a light-dependent type (LDR1). This is the type of sensor that was used in the Light/Dark Indicator project ('Funtronics' project No. 4, featured in Issue 51 of 'Electronics'). If LDR1 is in darkness, it has a very high resistance, and so the circuit operates at a low frequency. In fact, if it is dark enough the circuit will stop working altogether. Increasing the light level gives higher pitches, until normal daylight levels are reached. Increasing the brightness above these levels produces little change in the output frequency.

Getting it Together

Firstly, read through this section and then *carefully* follow its instructions, one step at a time. Refer to the photographs of the finished project if this helps.

1. Cut out the component guide-sheet provided with the kit (which is a full-size copy of Figure 2), and glue it to the top of the plastic board. Paper glue or gum should be okay. Do not soak the paper with glue, a few small 'dabs' will do.

2. Fit the link-wires to the board using the self-tapping screws and washers provided. The link-wires are made from bare wire. Loop the wire, in a *clockwise* direction around each screw to which it must connect, taking the wire under the washers. Do not fully tighten a screw until all the leads that are under it are in place, and do not over-tighten the screws, otherwise the plastic board may be damaged. Be careful not to trap the bodies of any components under washers when tightening the screws.

Just below R3, one wire crosses over another, and it is very important that these wires do not touch together. For this reason, some sleeving is supplied in the kit to cover the bare wires.

3. Recognise and fit the components, in the order given below, using the same method as for the link wires. Cut the components' wires so that they are just long enough to loop around the screws; otherwise long leads left flapping around may touch each other (this is known as a 'short-circuit') and stop your circuit from working. This is particularly important in the sections of the board around TR1 and TR2.

Components

a) The first components to be fitted are Resistors R1,2,3 and 4. These are small sausage-like components having a leadout wire at each end, and several coloured bands around their bodies. These coloured bands represent the value of the resistor; the resistor colour code is featured

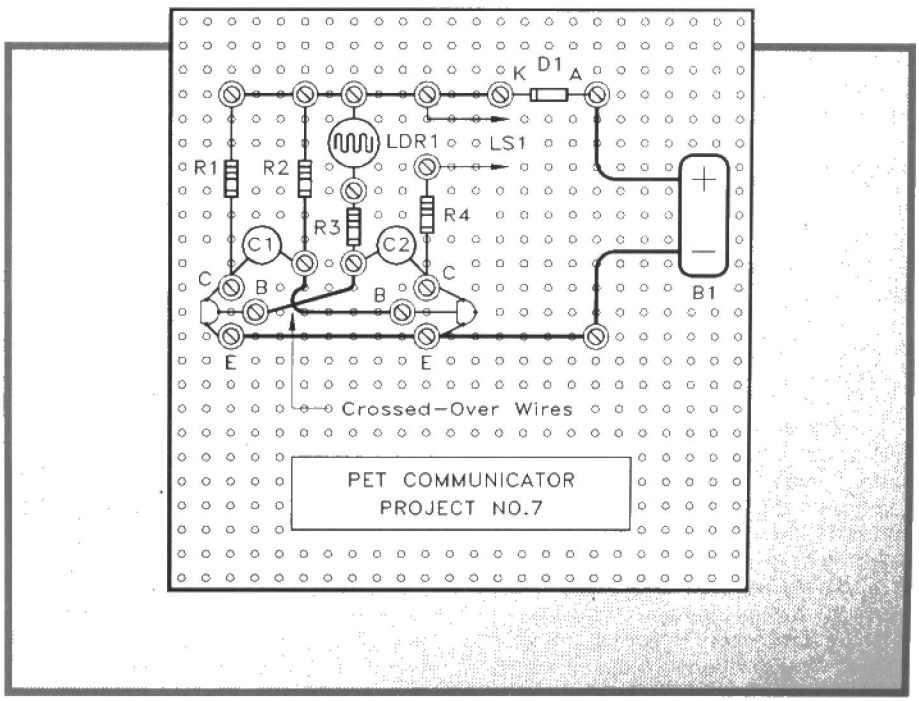


Figure 2. The component guide-sheet for the Pet Communicator.

in the Constructors' Guide. For each resistor, the colours (and value) are as follows:

Resistor	Band Colours	Value
R1	brown, red, red	1200Ω*
R2,3	brown, black, orange	10k
R4	brown, black, brown	100Ω

*(also written as 1K2)

For each resistor, there is a fourth band, coloured gold, which tells us how near to the given value the resistor is likely to be (in this case, there may be a difference of 5% or less) This fourth band is known as the 'tolerance' band, while the first three bands, shown in the above table, tell us the value of the resistor. Unlike diodes or transistors, it does not matter which way round resistors are connected.

b) The next component to be fitted is D1, which is a small tube-like component having a lead at each end of its black body. D1 must be connected the right way round (in other words, D1 is a 'polarised' component). Its 'polarity', which tells us the way in which it must be positioned, is indicated by a white (or silver) band close to one end of the body. D1, its circuit symbol and connections, are shown in Figure 3. The diode should be fitted so that the band lines up with the band on the drawing of the diode on the guide-sheet.

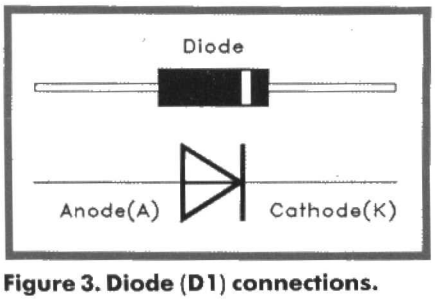


Figure 3. Diode (D1) connections.

c) C1 and C2, the capacitors, look like little green blobs with two wires coming from the base. As with most capacitors (with the exception of electrolytic and tantalum bead types) it does not matter which way round they are connected. Each should have its value of 0·1 μF included amongst its markings. In most cases this will be shown as 104 (10 with 4 '0's at the end, meaning 100,000 picofarads, which represents the same value.)

d) TR1 and TR2 should be fitted to the board next; these have a small black plastic body and three leadout wires. They are marked with their type number, which in each case is 'BC548'. Other markings may also be present; you will have to get used to picking out the important markings on chips and transistors (and ignoring the others!). You must ensure that TR1 and TR2 are fitted to the board correctly. Figure 4 shows which

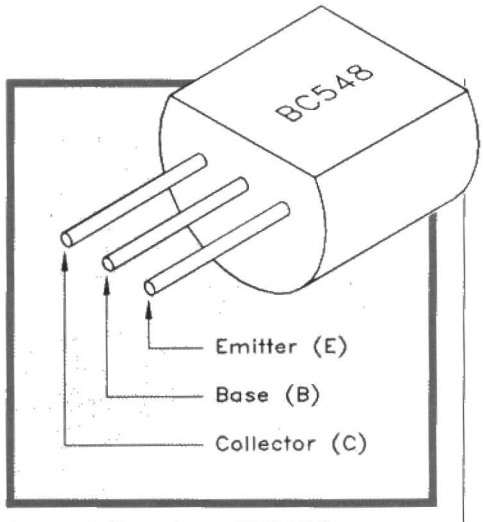


Figure 4. Transistor (TR1,TR2) connections.

lead is which, making this task easy.

e) Next, fit LDR1, which is a thick disc-shaped component having two lead-out wires. The shiny surface with the visible zig-zag 'pattern' is the light sensitive one, and should face upwards. The distinctive pattern is in fact the track of light sensitive material (cadmium sulphide in this case). LDR1, being a resistor, can be connected either way round.

f) The loudspeaker (LS1) is a type of component that we have not used in previous 'Funtronics' projects. It is the largest (and heaviest) component supplied in the kit (except for the board, of course), and can be identified by its black paper cone, which is about 50mm (or so) across. The cone is the part of the loudspeaker that literally pumps out the sound-waves as it moves backwards and forwards. Be careful not to damage the cone, which is made from a delicate paper-like material; sticking a finger through it might not stop the speaker from working, but will not improve its performance either!

LS1 may be connected either way round; use two pieces of insulated wire to connect it to the board. Use wire strippers to remove about ten millimetres of insulation from both ends of each lead. Connect the wires to the tags on the loudspeaker first. The wire is multi-stranded, which means that the metal core consists of several very fine wires. The bare ends of the leads should be twisted together to prevent the wires from splaying apart and breaking off – in addition to making them easier to deal with. Thread each multi-strand wire through the hole in the corresponding tag, loop it back on itself, and then twist it tightly to make a reliable connection. It *is* a good idea to use some glue, or a lump of 'Blu-Tack', to fix the rear of the loudspeaker to a vacant area of the board.

g) Lastly, fit the battery connector and battery, B1; the connector must be attached to the board with its coloured leads the correct way round.

The battery connector has two press-stud clips on a piece of plastic and two wires coming from it, coloured red and black. The red and black leads should be connected as shown on the layout sheet. The 9V PP3 type battery should be connected to the battery connector, it will only fit properly one way round.

Testing and Use

Using the 100nF components for C1 and C2 initially, the finished unit should produce a tone when a battery is connected. By varying the light level received by LDR1 (by moving your hand towards or away from it) you should be able to vary the pitch of the tone; brightness gives high tones, while darkness gives low frequencies. In very low light levels, the unit will cease functioning.

Using the 10nF capacitors for C1 and C2 will give a range of tones about ten times higher in pitch. At high light levels the tone should be high-pitched – but still audible to most people.

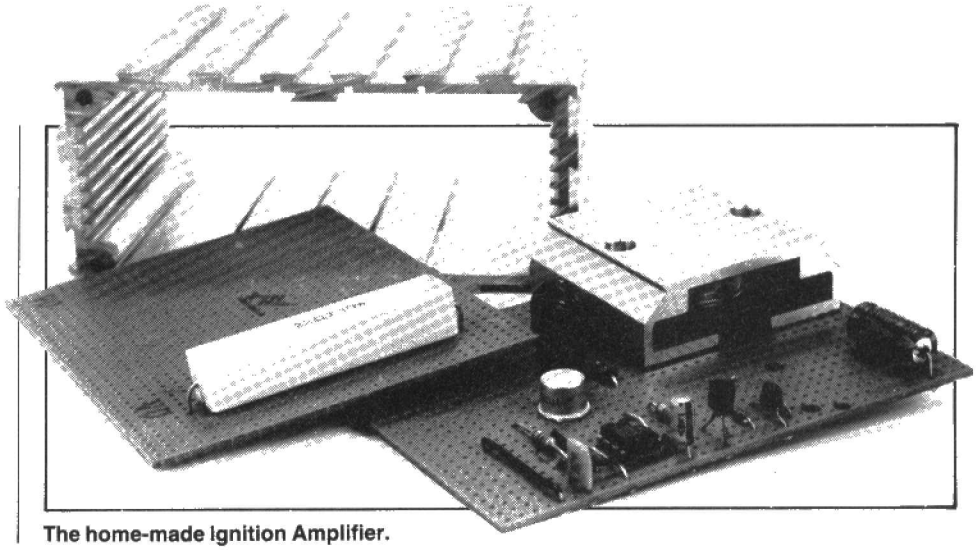
If the unit does not produce a tone, disconnect the battery at once and check the wiring again. In particular, make sure that D1, TR1, TR2, and the battery are fitted the right way round. Also check that both of the leads to LS1 are making good contact.

By varying the amount of light on LDR1 you can create a range of tones. It is possible to train your dog or cat to respond to these sounds. Just before your four-legged friend is fed, make a certain sound using the Communicator. After a week or so, the animal may associate food with this sound. Just the mere sound of the Communicator should then bring the pet to the food bowl in anticipation. You can make a variety of tones using the unit, so you might be able to get the animal to respond to different sounds in different ways. For example, you could try different sounds for walkies, going to bed, etc.

To use the unit as an alarm, 100nF capacitors should be used for C1 and C2. If you place the unit in a normally dark spot it should stay silent. If someone shines a torch on it, or turns the light on, the alarm will sound a warning note. By using a long lead to connect LS1 to the main unit, it can be mounted well away from the main unit.

Availability

The Funtronics Pet Communicator is available from Maplin Electronics, through our chain of regional stores, or by mail order, **Order Code LT01B Price £3.95.**



The home-made Ignition Amplifier.

ELECTRONIC IGNITION

PART TWO

BY MIKE HOLMES

Important Editorial Note

The circuits and information presented here must be considered as for interest only, no warranty is given for suitability in particular applications, reliability or circuit operation. It is strongly recommended that readers do not attempt to modify existing ignition circuits unless they are experienced in all aspects of automotive electro-mechanics and are fully aware of the consequences on safety, reliability and emission levels that any modifications may cause.

Last Time

In Part one we looked at some basic principles and essential requirements for spark ignition using the switched coil technique. Now all this information has been put to good use to actually build a working amplifier using discrete components. As mentioned in Part one, this may be done to replace an original item which has failed, or as an upgrade to an existing ignition system, later models of which have electronic ignition as standard, by obtaining the magnetic timing sensor and fittings from a source such as a car breaker. Alternatively it can be easily pressed into service as the essential part of 'transistor assisted ignition', more of which later. The exercise serves to illustrate the practical problems which are encountered and must be overcome.

A Real Working Amplifier

Figure 7 shows a circuit which is the culmination of six months development, including testing 'in the field' on-board a real motor vehicle which, for earlier versions, proved to be destructive (to the circuit, not the vehicle). Such is the way of research and development, and these events made definite indications that the unit should be 1) electrically robust; 2) mechanically robust; and 3) utterly weatherproof.

Referring to Figure 7, the input stage is as described for the hypothetical amplifier at the end of Part 1, with the combined diode junctions of both D1 and TR1 forming the input threshold level, and having R1 as a protective current limiter. C1 is merely an HF filter in conjunction with R1 and does not provide any rev limiting.

To reduce component count, the fast switching action needed to sharpen the pulse produced by TR1 is provided by IC1, a 555 timer IC used in an unusual way. Instead of being employed in a conventional (for the IC) manner as a monostable etc., both trigger and threshold inputs (pins 2 and 6) are tied together to exploit the behaviour of the internal bistable forcing a Schmitt trigger action. The 555 was chosen because the output structure can source the driver stage, TR2, directly without the need for any more transistor amplifiers.

While there is no input and TR1 is off, pins 2 and 6 of IC1 are high and the output pin 5 is low, so that TR2 is also off, allowing the bias resistor, R4, to saturate the main transistor switch for the ignition coil, TR3, and the coil is 'on'.

Upon an input ramp voltage from the timing sensor exceeding the combined threshold levels of D1 and TR1, TR1 conducts and quickly pulls the trigger input down to $<1/3$ of the supply level, causing IC1 to change state and switch on

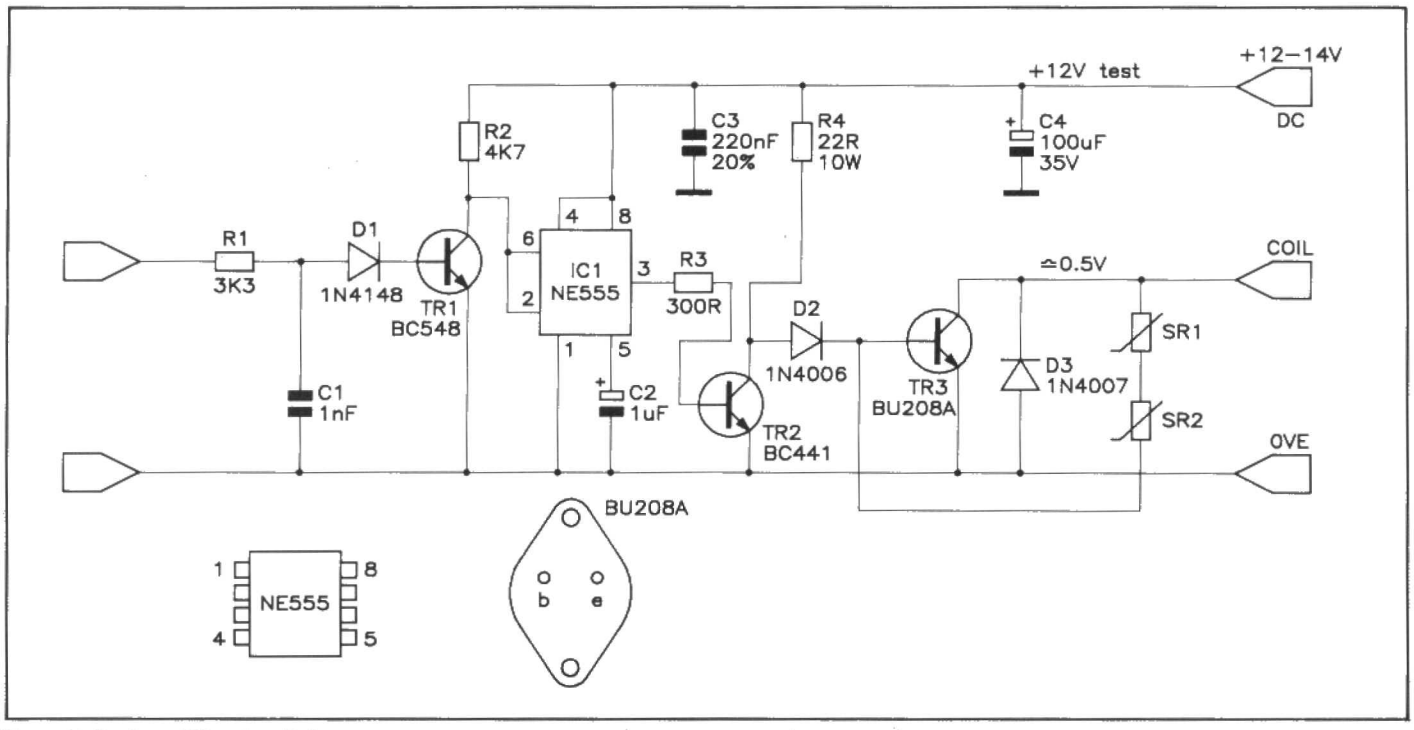


Figure 7. Real amplifier circuit diagram.

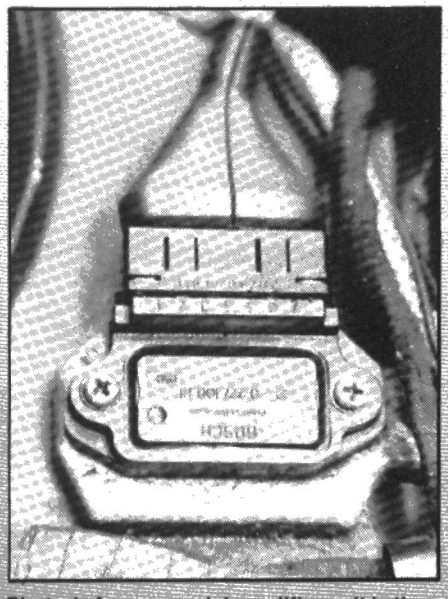


Photo 1. A commercial amplifier unit is tiny compared with the home-made version.

TR2, which clamps R4 to ground and deprives TR3 of base drive current. The coil is switched off. IC1 is reset when the ramp is completed as TR1 collector goes high again, and the system is ready to generate another spark.

Note that all stages use the 0V rail as the sole reference and are thus immune to supply rail fluctuations, which will occur often in the range of 12 – 13·8V, especially if an electro-mechanical regulator is employed, and can be less than 9V while the starter motor is giving the battery a hard time.

Electrical Safeguards

The other area of electrical weakness is concentrated on TR3. This is because of some horrible punishments that the ignition coil will try to inflict on this device. From the range of high voltage power transistors readily available the only one to prove itself electrically tough enough to be truly reliable is the long standing, TO3 packaged BU208 device designed for use in colour TV line timebases and switched-mode power supplies. The BU208A is preferred for its lowest saturated V_{ce}, essential to ensure maximum voltage drop across the coil and reduce power dissipation in the transistor itself to a minimum – it is the more expensive version, but that can't be helped. The device has a V_{ce} rating of 700V and a reasonable H_{fe}, which reduces bias resistor heat dissipation and power loss, as this component (R4) has a conservative value of 22Ω(!). However TR3 still needs two essential protection schemes.

One of these must cope with ignition coil back EMF, which, without a power sapping condenser (see Part 1), is excessive. But surely this can only occur without a spark plug as a load, else how can this happen where there is an air gap which must strike and conduct and thus limit both the coil's primary and secondary voltages? The truth is that, comparatively speaking, the air gap takes a long time to respond. Until this happens it is as if there were no load at all and the coil shoves up the potential enormously. A very simple calculation can be made to get some idea of the theoretical magnitude of back EMF from a coil by:

$$\frac{\text{voltage drop across coil}}{\text{commutation time}}$$

where commutation time is the time taken for the switching device to switch off, which is of course not truly instantaneous. Assuming for example a commutation time of 100ns, which even for a BU208 is very much on the slow side, we get (in theory):

$$\frac{12V}{100ns} = 120{,}000V!$$

This is what we get on the *primary side*. In practice however it will be precisely 1,400V. Why so? Because this is the designed collector to base (V_{cb}) limit of a BU208, never mind that this value is double the maximum V_{ce}! The base/collector junction is breaking down in the reverse direction like a Zener diode, and it is not supposed to be used in this way. Damage is cumulative and the device may fail after even some tens of hours of apparently fault free operation.

The voltage limiting protection scheme in Figure 7 comprises identical components SR1 and SR2, which are nothing more elaborate than two mains transient suppressors in series. This component is a Metal Oxide Varistor (MOV), the resistance of which is voltage dependent. It has a knee voltage of 1·414 x 240V (340V), which is the peak value of the mains supply. Up to this point its resistance is high, but reduces considerably as soon as its knee voltage is exceeded, and is normally used to prevent voltage spikes which would otherwise exceed the peak mains value from entering mains powered equipment.

Originally it was assumed that two of these in series would be sufficient to limit coil EMF to 680V (within the max. V_{ce} of TR3) on their own, but in reality they are unable to cope. Consequently they have to achieve the desired objective by the alternative means of providing feedback to TR3 base and letting TR3 do the actual limiting instead. In other words, TR3 is made to switch off up to the 680V point, and then holds this until the EMF value falls below this level before switching off properly. Reverse blocking diode D2

detours the current from SR2 to TR3 base so that it doesn't go straight to ground via TR2.

The other protection scheme is a provision to prevent the voltage across TR3 being reversed, i.e. <0V, which is inevitable since the ignition coil still resonates after the spark extinguishes, for while there is no condenser there is still inter-wiring capacitance, together with that between TR3's case and its heatsink. The ringing is now high frequency and very short in duration, but still very much alive and kicking. This is the duty of D3.

Insulation Problems

Experience has indicated that a greaseless TO3 insulator is more reliable than the traditional mica variety for heatsink mounting. If the mica is not 100% perfect then any cracks are weaknesses

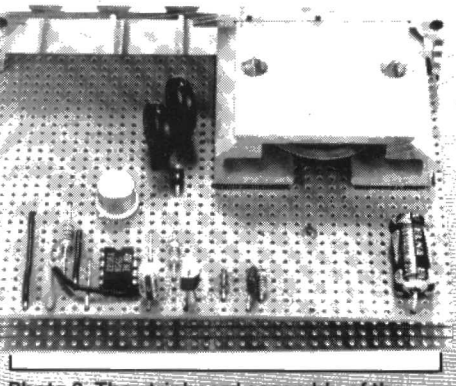


Photo 3. The stripboard assembly of the circuit of Figure 7 with heatsink in position and remote R4 on separate board.

which can be perforated by the high voltage pulses. In the final design the unit was housed in an extruded modular alloy case (see Photo 2), with which a slide-in TO3 compatible heatsink was used. Although this item comes complete with screws, nuts and insulator bushes, insulator sleeves were cut from separately available TO3 bushes and pressed into the holes before mounting the entire assembly in the correct position on the stripboard ready to slide into the case, as can be seen in Photo 3.

Mechanical Considerations

Components which are at risk from vibration, e.g. upright PCB mounted electrolytics, were supported at their base with blobs of flexible rubber sealant. IC1 was soldered directly without a socket, or else in service oxidation may cause continuity problems. R4 is a ceramic block encapsulated 10 watt component and was fitted on a separate board such that its top surface is in contact with the case,

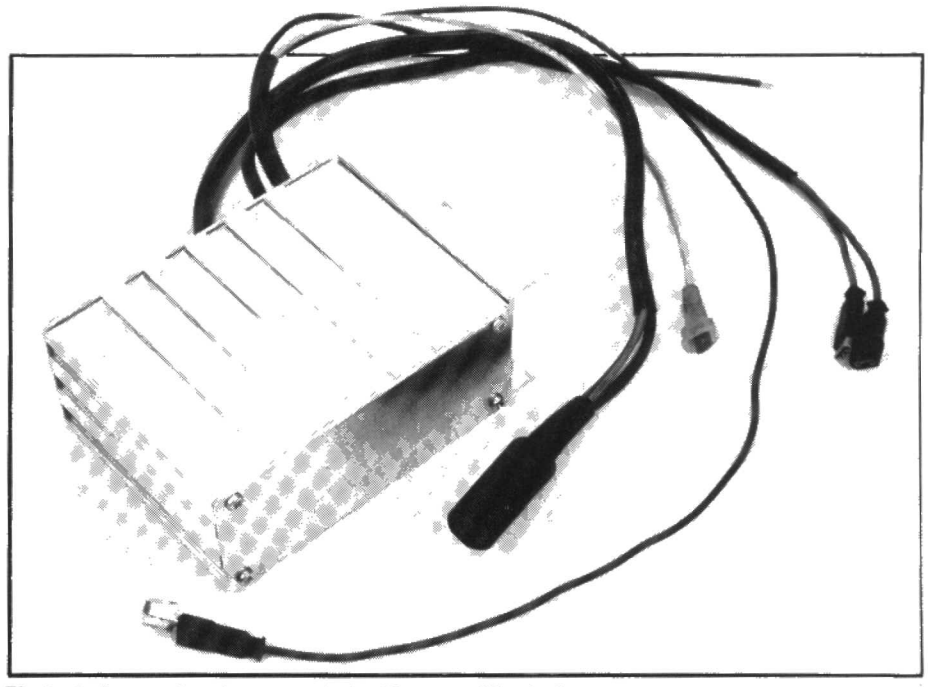


Photo 2. A complete home-made ignition amplifier in its case.

and soldered in this position during a test fitting. At final fitting this top face was smeared with heatsink compound to fill-in the rough surface. R4 then uses the case as a heatsink.

The reason for the enormous number of external cables, evident in the example shown in Photo 2, is that this unit contains an identical *pair* of these amplifiers for a specialised motorcycle application, so there was plenty of room for one in the case!

Transistor Assisted Ignition

Transistor assisted ignition simply means that a 'conventional' mechanical timing switch, such as a contact breaker, is not actually used to switch the coil directly but controls a solid state switch instead. The circuit of Figure 7 could be used in this role, by merely adding an extra 22Ω 10W resistor between the input and supply, as a load for the contact breaker. This will greatly increase the life of a pair of normal contact breakers, which will consequently require much less frequent timing readjustment, after which the vehicle will operate efficiently for longer periods with less damage to the environment. In addition, the switching speed is faster making more energy available to the spark, although actual improvement is difficult to measure.

It is worth a mention however that the ignition coil must be a 'normal spec.' type with a resistance of 3 – 4Ω, and *not* a high current, high energy type, these types will destroy the amplifier!

Testing

It was thought prudent to check the operation of the amplifier before fitting into the vehicle. A simple test required a 12V power supply of up to 4A output (or a car battery), and a spare ignition coil. The amplifier on its own draws approx 500 to 600mA. By wrapping some tinned copper wire around the '+' terminal of the coil and

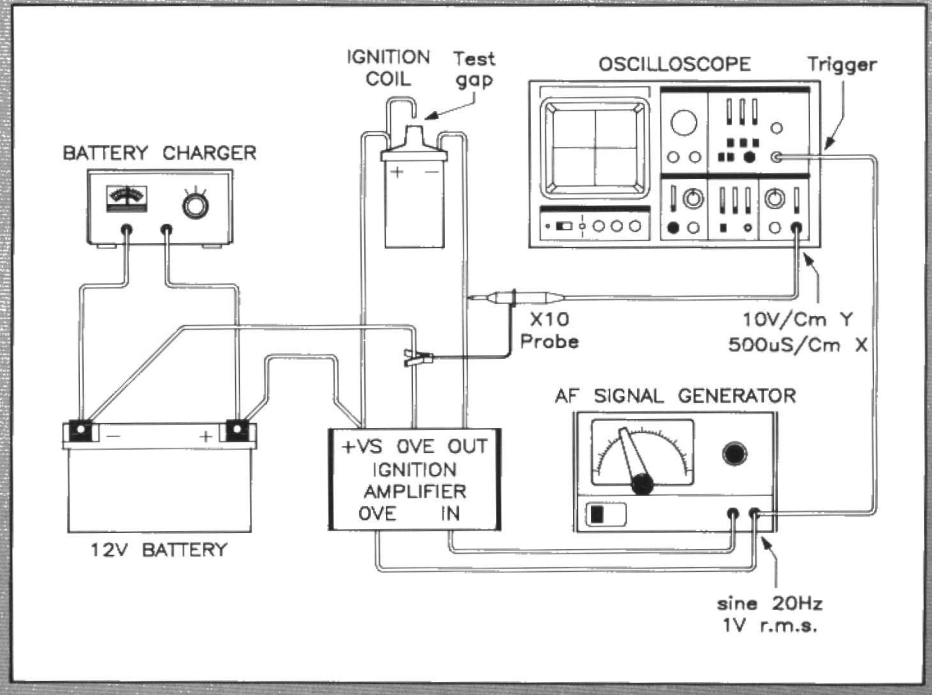


Figure 8. Test rig for monitoring amplifier output with a 'scope.

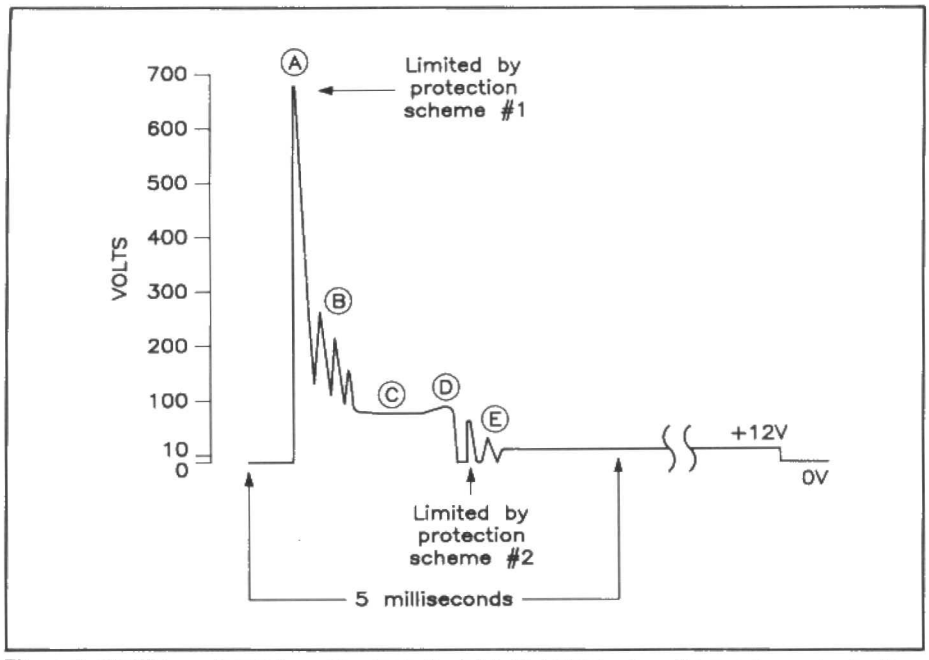


Figure 9. Oscillograph produced by test rig: (a) initial EMF pulse; (b) spark gap ionisation time; (c) gap conduction time; (d) gap extinguishing moment; (e) ringing period.

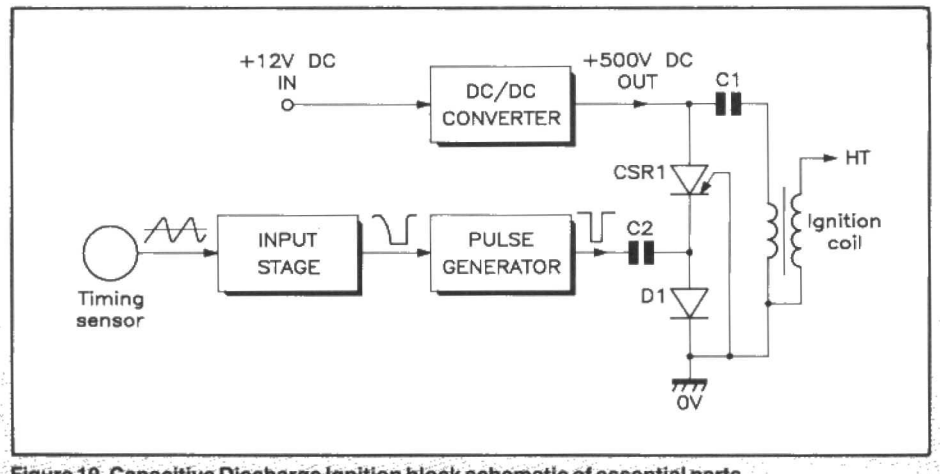


Figure 10. Capacitive Discharge Ignition block schematic of essential parts.

looping the other end into the HT socket, a simple spark gap was formed. This type of system must not operate without a spark gap for a load, or else it is likely to fail if such a load is not provided.

With the coil wired in, the repeated application of a 1·5V cell to the input produced crackingly healthy blue sparks. For the transistor assisted version, earthing the input lead for 'on' and release for 'off' had the same effect. While 'on' the output ('–' terminal on coil) will be 0·5 to 1V.

A more elaborate test rig is illustrated in Figure 8. The battery charger simulates an active charging system. The primary coil voltage can be monitored by an oscilloscope using a x10 probe for an effective sensitivity of 100V/cm on the 10V/cm range. It is *very important* that the probe's trimmer be precisely calibrated for an exactly flat frequency response using a high quality square wave signal! The coil's primary winding provides a good representation of what's going on at the secondary output end, which can be seen on an 8cm high graticule with the baseline set on the bottom or second line. It was necessary to turn the brightness up and shade the screen well, as the whole event is over in less than 3 milliseconds, the trace looks like Figure 9.

Note that the primary's representation of the gap conduction voltage level is quite low at 80 or 90V, but this is because the air gap is at normal atmospheric pressure. While providing sparks for a real engine this level actually wanders about all over the place in direct proportion to the gas density in the combustion chamber, being at its greatest while this is high during acceleration, and lowest during the over-run while the throttle is closed. It is for this reason that the upper limit is designed at 680V and the BU208 chosen in order to provide plenty of 'headroom'; a different output stage with a lower voltage transistor *will not work properly* (as it stands the design has been found to handle compression ratios of >10:1). This behaviour also explains why any insulation weakness always breaks down during acceleration. Such a breakdown is usually total, as I found out the hard way, leaving me stranded, so take note!

C.D.I.

Who remembers D.I.Y. clip-on ignition boosters? At one point during the late 70's the popular motor accessory shops were crawling alive with these things. The selling point was the third principle (as mentioned in Part one) – Capacitive Discharge Ignition.

C.D.I. employs the ignition coil in a totally different manner, namely as a form of pulse transformer. The advantage is that the coil is no longer an appreciable part of the electrical load as in a more conventional switched system; it does not have a heavy current flowing in it for a large part of the time and consequently has an easier life, promoting reliability. In addition, overall power consumption for the ignition system as a whole is much lower and is in fact proportional to engine speed. As well as by the much reduced power requirement, cold winter starting is aided by the very high energy spark that C.D.I. can generate, which, if the designer was careful, is still available even if the battery voltage is very low during starting.

C.D.I. is electrically efficient like no other alternative system, producing enormous sparks for a miserly few hundred milliamps of supply current. Past experiments by this author with home grown C.D.I. designs have produced sparks of 1½ inches! Figure 10 shows a typical system in block form, and individual designs do not deviate much from this.

The heart of the system is a DC/DC converter, which produces a high voltage first (as opposed to the switched method which derives it at spark time by switching the coil off) directly from the low tension supply. It is stored by capacitor C1 which is in series with the coil primary winding.

The input stage receives a signal from a magnetic or other form of timing sensor or a contact breaker, and trips a pulse generator, usually a monostable. The output pulse triggers on CSR1, which clamps C1's 'live end' to ground. The coil primary suddenly finds something in the region of 500V across it, and commences discharging C1. In the process, the discharge current induces a current in the secondary winding, where the primary voltage is multiplied by the turns ratio, producing a spark at the HT output. The counter-EMF from the coil primary that follows turns CSR1 off again. While all this is going on, the converter's output is effectively short-circuited to earth, and it must be designed in such a way that it is not damaged by this.

The system is that simple, and easy to design, but latterly is by and large 'not taken seriously' by most motor manufacturers. Why should this be? Because of two inherent, unavoidable flaws in the principle.

One of these is to do with spark conduction time. The truth is that this depends on capacitor discharge time, and as a result can be appreciably shorter than that of a conventionally switched coil. This means less gap conduction time in the combustion chamber and, to be blunt,

less than ideal ignition of the fuel gas. In reality a better burn (and less waste and pollutants) results from a medium energy long spark than a high energy short one – although this also depends on how the combustion chamber design can make the best use of it; with some older shapes, which are so inefficient in the first place, it won't make much difference. The obvious answer is to increase the value of C1 to increase conduction time, but this aggravates the second problem.

Which is that said capacitor should be completely recharged prior to the next spark moment. Suppose that C1 were increased to 1μF to provide a 4-cylinder engine with reasonable sparks up to its peak output speed of 6,000 r.p.m. This requires 200 sparks per second, further requiring C1 to be recharged in the space of <5ms. This needs a charging current of 100mA, which can be proved by:

$$\frac{100{,}000\mu A}{1\mu F} \times 5ms = 500V$$

and the average power consumption of the converter increases, by coincidence, to 50 watts – I say by coincidence because this is also the average for a conventionally used ignition coil. In practice the spark strength of C.D.I. always drops off along a steadily worsening curve at higher r.p.m., aggravating incomplete combustion, already compromised by gas flow problems and such. This is not to say that switched ignition doesn't have a similar behaviour, but the roll-off of a switched coil is less acute, and in any case it is easier to select or manufacture the coil for the job required.

To be fair though C.D.I. is not a totally duff idea, but, should you be toying with the idea of investigating the principle yourself, be advised that, in order to be able to deliver the required goods with any semblance of real usefulness, the converter should follow a high frequency type of switched mode power supply principle, using a ferrite cored transformer, and *not* use a mains transformer 'in reverse'! Mains transformers are designed to tap power from the mains at mains frequency, and are not very good at doing anything else. Given the 'short-circuited' output problem, the converter could be a single-ended flyback converter design.

The Future

One possible forthcoming innovation for cars of the future is currently being investigated in the United States, namely distributor-less ignition. Instead of a mechanical rotor delivering the HT current to the required plug as necessary, one iteration of the principle is to use high voltage rectifiers in a 'floating' secondary circuit to steer HT to the desired *pair* of cylinders in a 4-cylinder engine, the other cylinder, which does not need a spark, is on its exhaust stroke and so a spark here is known as a 'wasted spark'. The ignition coil primary is double-ended and operated in 'push-pull' mode by a pair of switching transistors; the direction of the secondary pulse determines which pair of plugs will receive the current via the diode matrix, and the transistors will no doubt be under the control of an engine management computer.

A variation will use two ignition coils, also with floating 'open-ended' secondary windings but terminated straight to a spark plug at each end. Again the relevant pair of pistons move together but their valve timing is 180° out of phase, so that while one is on its compression stroke, the other is on its exhaust stroke.

In actual fact motorcycles have featured duplicated complete ignition systems, and the 'wasted spark' technique for many years, and it is only a question of time before motor cars follow suit and become equally distributorless.

And Finally

These, and many other subjects concerning the application of electronics in cars, can be found in the book 'Understanding Automotive Electronics' by W.B. Ribbens and N.P. Mansour, Maplin order code WA44X. I also take this opportunity to acknowledge the assistance of Mistral Engineering of Carysfort Road, London, and our very own Robert Ball for his helpful ideas and observations.

MAPLIN'S TOP TWENTY KITS

POSITION			DESCRIPTION OF KIT	ORDER AS	PRICE	DETAILS IN		
1.	(1)	▲	Live Wire Detector	LK63T	£ 4.25	Magazine	48	(XA48C)
2.	(5)	▲	L200 Data File	LP69A	£ 3.95	Magazine	46	(XA46A)
3.	(6)	▲	MOSFET Amplifier	LP56L	£19.95	Magazine	41	(XA41U)
4.	(2)	▼	Car Battery Monitor	LK42V	£ 7.95	Magazine	37	(XA37S)
5.	(3)	▼	Courtesy Light Extender	LP66W	£ 2.75	Magazine	44	(XA44X)
6.	(7)	▲	TDA7052 Kit	LP16S	£ 4.45	Magazine	37	(XA37S)
7.	(4)	▼	Mini Metal Detector	LM35Q	£ 6.45	Magazine	48	(XA48C)
8.	(8)	▲	Vehicle Intruder Alarm	LP65V	£ 9.95	Magazine	46	(XA46A)
9.	(9)	▲	1:300 Timer	LP30H	£ 4.95	Magazine	38	(XA38R)
10.	(11)	▲	Low Cost Alarm	LP72P	£12.95	Magazine	45	(XA45Y)
11.	(14)	▲	PWM Motor Driver	LK54J	£ 9.95	Best of Book	3	(XC03D)
12.	(10)	▼	Partylite	LW93B	£10.25	Catalogue	'92	(CA09K)
13.	(13)	▲	MSM6322 Data File	LP58N	£11.45	Magazine	44	(XA44X)
14.	(15)	▲	IBM Expansion Sys	LP12N	£18.25	Magazine	43	(XA43C)
15.	(16)	▲	LM383 8W Amplifier	LW36P	£ 7.45	Catalogue	'92	(CA09K)
16.	(18)	▲	TDA2822 Amplifier	LP03D	£ 6.95	Magazine	34	(XA34M)
17.	(20)	▲	LM386 Amplifier	LM76H	£ 3.75	Magazine	29	(XA29G)
18.	(17)	▼	I/R Prox. Detector	LM13P	£ 9.95	Projects	20	(XA20W)
19.	(19)	▲	15W Amplifier	YQ43W	£ 7.45	Catalogue	'92	(CA09K)
20.	(–)	RE-ENTRY	I/R Remote Tester	LP53H	£ 6.45	Magazine	44	(XA44X)

Over 150 other kits also available. All kits supplied with instructions.

The descriptions are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate project book, magazine or catalogue mentioned in the list above.

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2ND Time Around

Particular projects from the Maplin range have proven to be very popular over the years; but unfortunately, technology and components often change, thus resulting in these projects becoming obsolete. However, some projects will be re-published with updates and improvements as necessary under the series entitled '2nd Time Around'.

Close-up of the complete detector PCB.

INFRA-RED PROXIMITY DETECTOR

Commercially available body-heat-movement-detection-systems, although very sophisticated in their operation, can be rather expensive for use in limited applications where short-range coverage is required. This I/R proximity detector has been designed as a simple, low-cost system for detecting heat changes, movement of a warm body, etc., such as those emitted from the human body. The unit responds to a definite change or disturbance in ambient – or background – heat levels and could be placed across a doorway or stairs to register movement in those areas.

Features:

- ★ **Short-Range, Heat/Movement Detector**
- ★ **Uses Latest Pyro-electric Device**
- ★ **Low Power Consumption for Long Battery Life**

Application:

- ★ **Ideal for Doorways, Stairs and Similar Proximity Systems**

Pyroelectrics

The E100SV1 sensor uses a ceramic, ferroelectric element, which has the property of producing an electrical change due to a change in polarisation intensity. If a moving object enters the field of view of this sensor, changes in infra-red energy levels occur due to a difference in temperature between this object and the background. Infra-red energy is converted into heat by the surface electrode of the element, thus causing a change in temperature within the element itself, and a small electric charge is created as a result (see Figure 1).

This small charge appears across the gate resistance Rg in Figure 2, and is impedance buffered by the FET source follower, where a change in voltage appears across source resistance R13 (Figure 4).

A small DC bias voltage is produced across R13 by the quiescent current flowing through the FET while no signal is

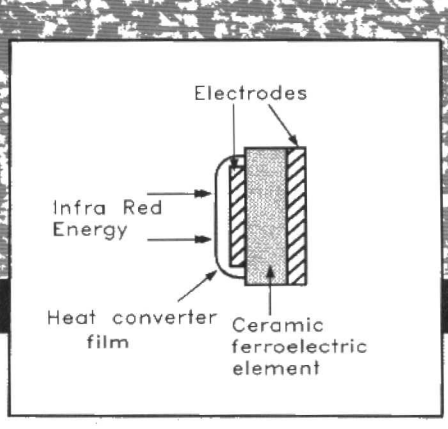


Figure 1. Pyroelectric element.

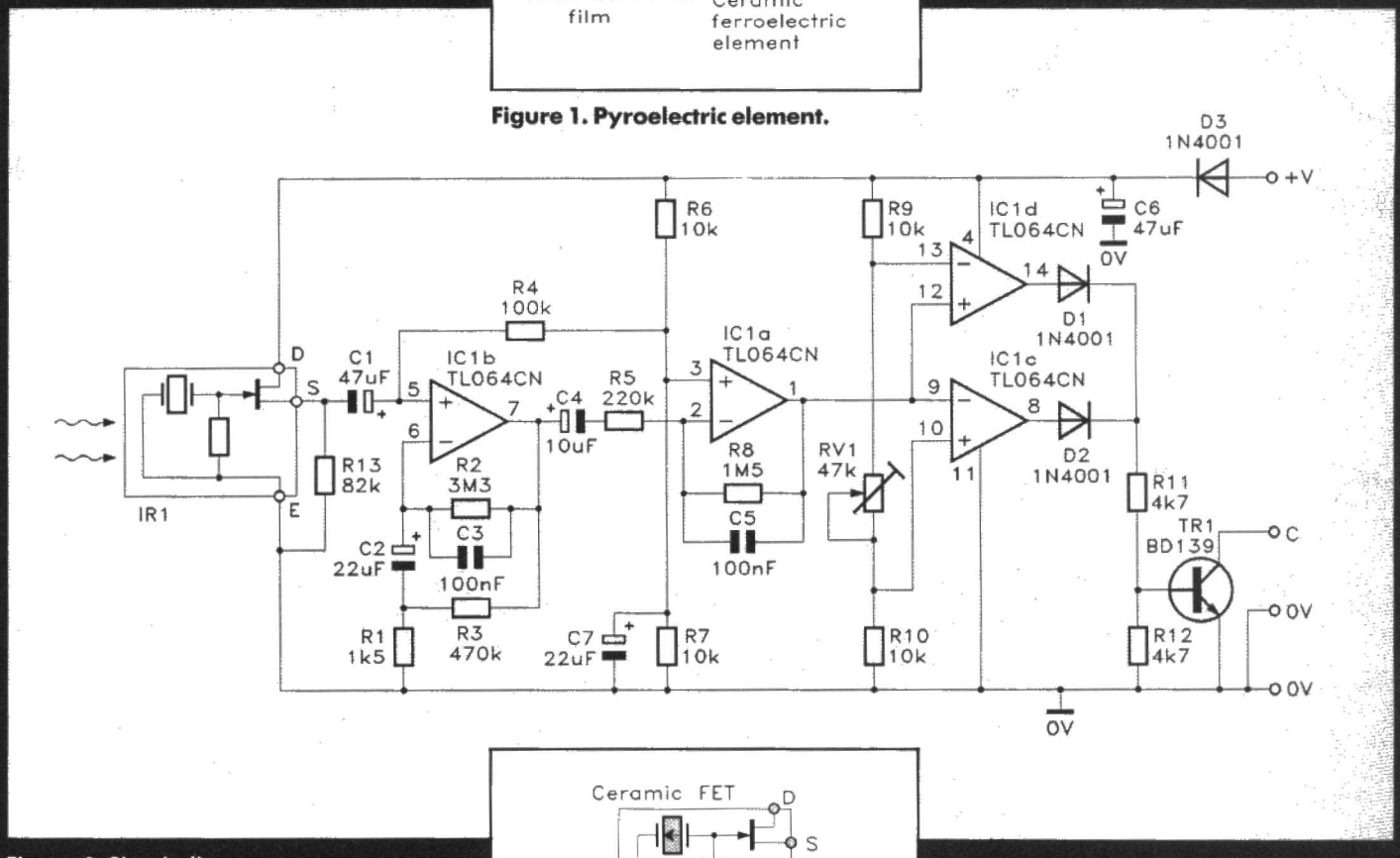


Figure 4. Circuit diagram.

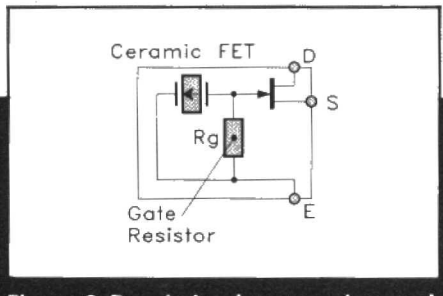


Figure 2. Proximity detector – internal.

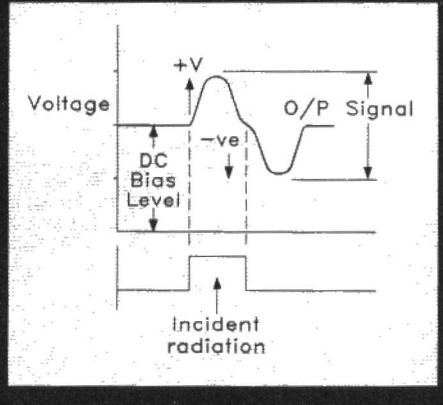


Figure 3. Source output voltage swing.

present, as can be seen in Figure 3. Output signals from the source terminal modulate the DC bias level with a $+V_e$ voltage swing.

In use, the voltage swing is very small, its amplitude being determined by the amount of incident energy available, which becomes smaller with increasing distance.

Done with Mirrors!

A negligible amount of energy is emitted from the human body which limits the effective working range of the module down to four feet or so. This range could be extended by increasing the sensitivity of the amplifier and developing velocity related filter circuits which would determine a given range of movement speeds and size of body.

An even more effective method is employed on commercial systems in the form of collecting lenses and optical amplifying concave mirrors. Problems associated with energy collecting systems are: movements in the air, sunlight 'modulated' through curtains and even small animals generating fluctuations in the infra-red energy background. To help overcome these sorts of problems, a multi-faceted, concave mirror is often used, which has the effect of expanding (or narrowing) the field of view into bands.

As an infra-red emitting source crosses the field of view, radiated energy bounces off these facets in a sequence. The sensor responds with a series of related output pulses; detection electronics can determine the size, velocity and direction of the source while it is moving. Sophisticated PIRs are readily available in the Maplin catalogue and are more suitable for security and alarm use than this particular system.

However, many applications exist where a simpler system is called for, especially for the home constructor!

Circuit Description

The circuit shown in Figure 4 consists of two amplifying stages, with low-pass filtering and a comparator threshold stage. Output voltage swings from the PIR are amplified by IC1b, which is configured as a non-inverting amplifier. The PIR receives energy from many sources, a mixed waveform would be produced at IC1b output, therefore C3 integrates continuous low-level signals and acts as a low-pass filter.

The somewhat unusual arrangement of resistors R1 and R4 allow C2 to charge slowly during initial power up. C2 is necessary for isolating IC1b $-V_e$ input from the 0V supply rail. With single supply op-amps, it is common to generate a half supply DC voltage reference to bias the differential inputs, thus allowing output voltage swings about this level. The effect of integration on the continuous input signals produces a very low-frequency output signal, which is applied to C2. The charge across C2 varies with the magnitude of the output signal (from Pin 7) and limits heavy transients which might saturate this stage.

IC1a is a standard inverting amplifier, again voltage referenced to half supply

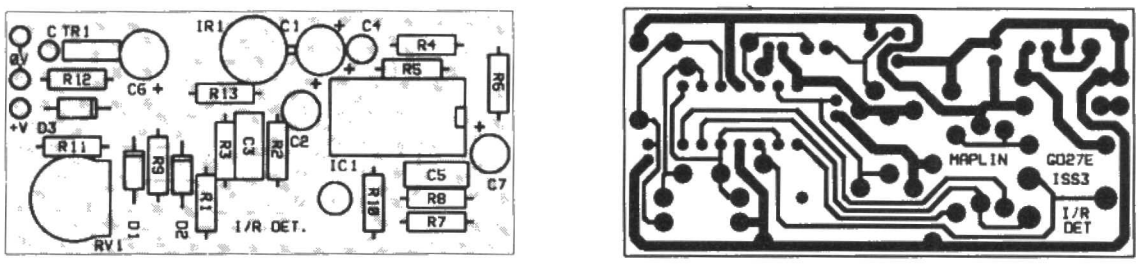


Figure 5. PCB legend and track.

by R6 and R7. C7 decouples the reference voltage to prevent comparator supply spikes from being introduced into the stage. IC1d and IC1c serve as a simple comparator. The threshold voltage reference (determining when the comparators will trigger) is set by RV1 in the potential divider chain R9 and R10.

Positive voltage swings from IC1a will trigger the IC1d comparator causing D1 to conduct, while negative swings trigger IC1c causing D2 to conduct. From Figure 3 it can be seen that the output voltage swing from the PIR is, firstly, in a positive direction and then secondly in a negative direction. The ultimate effect from the comparator output at R11 is, therefore, not one but two pulses turning on transistor TR1.

Either one of diodes D1 or D2 could be removed for single pulse output, and which particular one to remove must be decided under full operational conditions. TR1 is an open collector switch, which will sink external loads (sourced from their own external +V supply) to the 0V common rail when conducting.

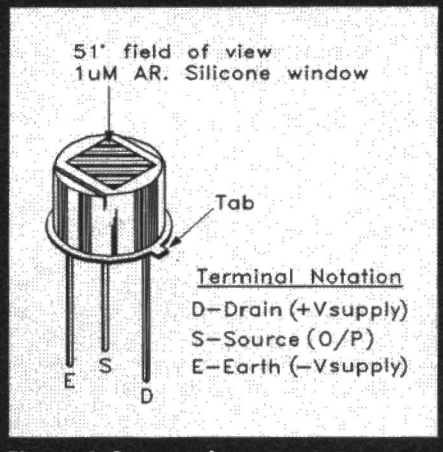


Figure 6. Sensor pin-outs.

Construction

For information on building details and components, refer to Figure 5 for the board layout and to the 'Constructors' Guide' supplied with this kit (if you do not intend to purchase the complete kit then see the Parts List for the order code of the Constructors' Guide). Identify and insert resistors R1 to R13. Solder these components and remove excess wire before continuing.

Mount diodes D1 to D3, and insert the four veropins into the holes marked with white circles. Next, insert a 14-Pin IC socket in position IC1 (taking note of the orientation notch), bend a few of the legs over the track pads to hold it in position. The PCB is quite small with tracks running close together, so a little extra care must be taken whilst soldering, as short circuits between tracks can easily occur.

Identify and insert capacitors C1 to C7. Polylayer type C3 should be fitted carefully to avoid breaking off the lead-out wires from the ends of the package. Fit preset RV1 and solder all components in position. Again cut off all excess leads, then fit TR1 and the sensor IR1 shown in Figure 6. One side of TR1 has a metal, heat transfer mounting plate fitted. Insert TR1 with this plate facing outward towards the edge of the PCB. The sensor IR1 shown in Figure 7 could be mounted vertically above the PCB, or horizontally off the PCB as detailed. In either case,

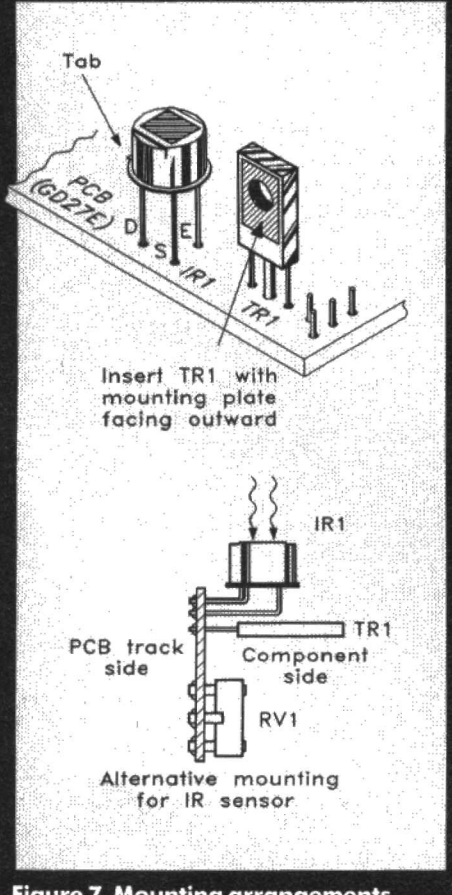


Figure 7. Mounting arrangements.

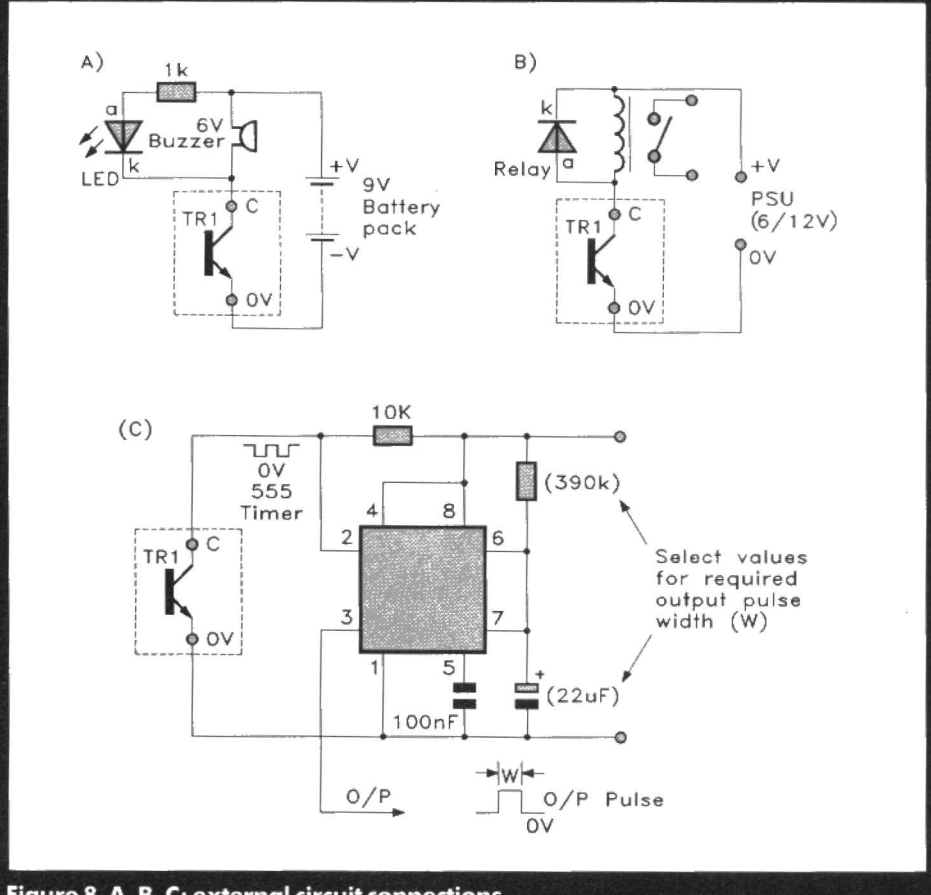


Figure 8. A, B, C: external circuit connections.

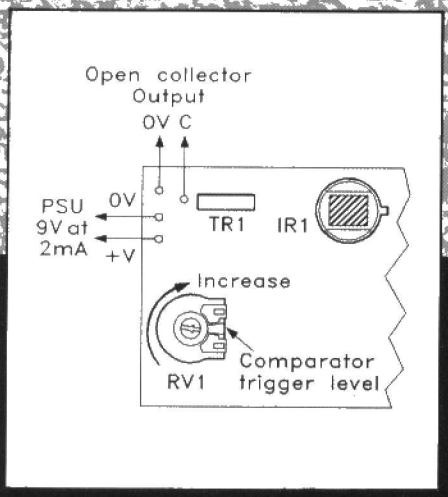


Figure 9. External PCB connections.

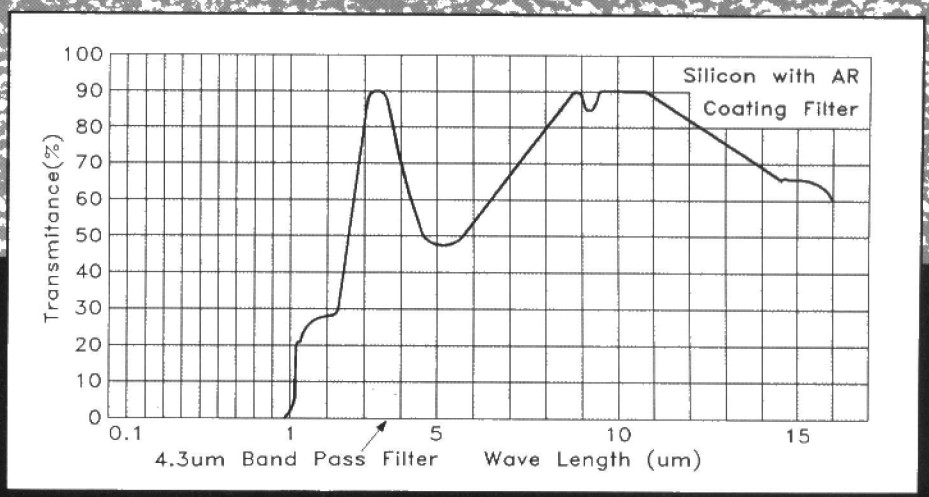


Figure 10. Spectral response of the sensor window.

mount the sensor as close as possible to the PCB in order to reduce noise induced into this area.

Either sensor mounting position will have to take into account the enclosure (case) requirements, and this is left to be fitted as required by the constructor. Last of all, fit a TL064 into the IC socket – taking note of the orientation; cut off all excess wires and clean up the track area to facilitate inspection.

Testing

Supply requirements for the module are 9V DC at 2 to 3mA. Current consumption is low, which allows long periods of use from small battery packs such as the PP3. Connect the battery $+V_e$ to the Pin marked +V, and $-V_e$ to either 0V Pin; diode D3 prevents damage to components in the event of accidental battery or supply reversal.

Check the supply current with an milliammeter which will be around 2·5mA for a minute or so dropping to between 1 and 1·5mA after this period. Current consumption increases by approximately 1mA while the comparator stages are operating.

The output transistor TR1 does not source current, but being open collector will sink current from an externally supplied load. Figure 8 suggests various methods of switching external loads, and diagram (a) could be used for testing purposes. Connect the LED cathode (k) to collector of TR1, the Pin marked C, then connect a 1kΩ resistor between the LED anode (a) and the $+V_e$ supply (battery + V_e or +V Pin).

If using the same battery for both module supply and LED supply, then the second battery $-V_e$ connection is not required (Pin 3).

Turn the comparator threshold control RV1 to half travel (Figure 9) then, after the initial 'warming up' period, move your hand across the sensor window. Do not poke the window with fingers as grease deposits will reduce sensitivity and may prevent operation completely! Figure 10 shows the spectral response expected in the window. The LED will light for a few seconds. If the LED is permanently aglow, turn the trigger level down by moving RV1 wiper anti-clockwise.

Using the Module

TR1 is not capable of switching heavy loads and should only be used with external systems up to 12V DC and current levels below 100mA. Relays could be used for controlling larger voltage/current devices (Figure 8b), or a timer could be employed to generate long operating periods once triggered (Figure 8c). On the prototype, a 6V at 35mA buzzer was used on a separate supply to good effect.

Any battery supplying the electronics should NOT also be used for supplying the external devices as well (if more than a simple LED arrangement is to be used). Battery connections to Pins 1 and 2 should be kept short – a PP3 clip lead is ideal for this – mount both module and battery together in the same housing with a suitable ON/OFF switch.

Sensing range is 4 to 5 feet, depending upon the sensor's field of view and variations in the light/heat background levels. A whole room, for instance, could not adequately be covered by this system, but doorways, narrow hallways and corridors are suitable areas. Another use for the module could be in a shower cubicle, using a timer circuit for controlling the water pump. Obviously, low voltage switching systems are important in this application.

INFRA-RED PROXIMITY DETECTOR PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1	Min Res 1k5	1	(M1K5)
R2	Min Res 3M3	1	(M3M3)
R3	Min Res 470k	1	(M470K)
R4	Min Res 100k	1	(M100K)
R5	Min Res 220k	1	(M220K)
R6,7,9,10	Min Res 10k	4	(M10K)
R8	Min Res 1M5	1	(M1M5)
R11,12	Min Res 4k7	2	(M4K7)
R13	Min Res 82k	1	(M82K)
RV1	Hor Encl Preset 47k	1	(UH05F)
CAPACITORS			
C1,6	Minelect 47µF 16V	2	(YY37S)
C2,7	Minelect 22µF 16V	2	(YY36P)
C3	Poly Layer 100nF	1	(WW41U)
C4	Minelect 10µF 16V	1	(YY34M)
C5	Minidisc 100nF 16V	1	(YR75S)
SEMICONDUCTORS			
D1,2,3	1N4001	3	(QL73Q)
TR1	BD139	1	(QF07H)
IC1	TL064CN	1	(RA66W)

MISCELLANEOUS			
IRD1	I/R Detector E100SV1	1	(UR69A)
	PCB	1	(GD27E)
	Pin 2145	1 Pkt	(FL24B)
	DIL Socket 14-pin	1	(BL18U)
	Instruction Leaflet	1	(XT72P)
	Constructors' Guide	1	(XH79L)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items are available as a kit which offers a saving over buying the parts separately.

Order As LT00A (I/R Prox Detectr Kit) Price £9.95.

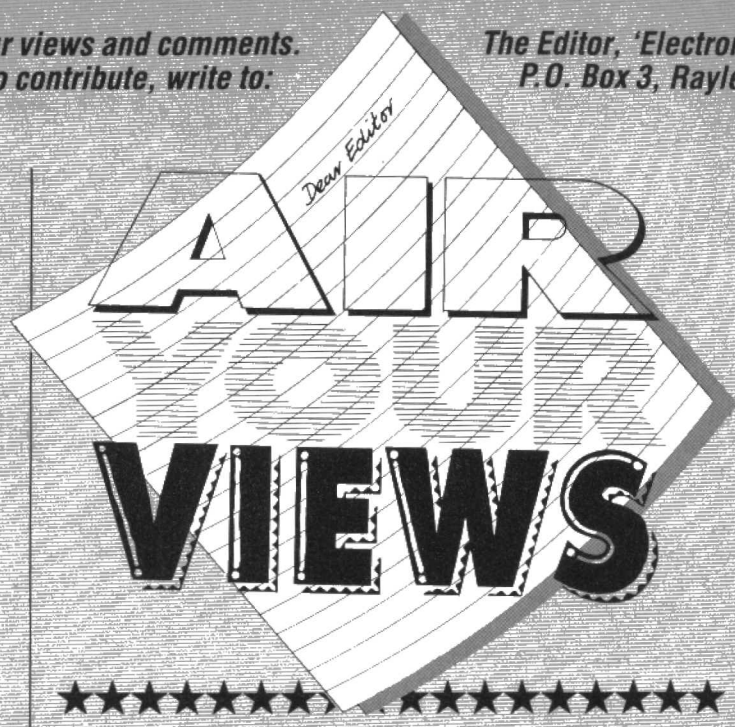
Please Note: where 'package' quantities are stated in the Parts List (e.g. packet, strip, reel etc.) the exact quantity required to build the project will be supplied in the kit.

The following new item (which is included in the kit) is also available separately, but is not shown in the 1992 Maplin Catalogue.

I/R Detector E100SV1 **Order As UR69A Price £5.95.**

A readers forum for your views and comments.
If you want to contribute, write to:

The Editor, 'Electronics – The Maplin Magazine'
P.O. Box 3, Rayleigh, Essex, SS6 8LR.



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S·T·A·R L·E·T·T·E·R

This issue, Peter Milburn from Cleveland, receives the Star Letter Award of a £5 Maplin Gift Token for his letter about fuses.

Make My Red LEDs Blue!

Dear Editor,
Looking through the Maplin catalogue in the Opto Electrical section, I came across the 3mm and 5mm Blue LEDs UL88V and UL89V, cost, £9.95 and £10.95 respectively. WOW!!! Why? When you could paint an ordinary water clear LED BLUE!
Mr D. Lee, Birkenhead, Merseyside

As regards blue LEDs, they are expensive because of the semiconductor material used and the manufacturing techniques employed. The device has to emit light in the upper blue spectrum, which is much more difficult to do than for red. It's no good painting a 'water clear' LED package, since the actual LED inside is again red, so that you will only end up with a dimmer red LED!

Getting Synchronised Properly

Dear Sir,
Some monitors with composite video inputs have a switch, and some TV's have a special channel, which is used when watching video cassette recordings. Does this use a special circuit? If so, why isn't this circuit always on? Is this why videos distort when played on some composite monitors?
Mark Parry, Wolverhampton

The line oscillator in your TV set contains an electronic 'flywheel' to 'iron out' any irregularities in the sync pulses caused by variations in signal propogation, interference, ghosting and the like. Normally, the time constant of this circuit is fairly long otherwise the line oscillator could 'trigger' at the incorrect time.
The average VCR suffers, to a greater or lesser extent, depending on its age and condition, from wow and flutter. This, coupled with the recording method employed, causes sync timing instabilities. To compensate for this, the TV has an 'A/V' mode, in which the time constant is shortened. Thus the TV's line oscillator will respond rapidly to these sporadic changes in sync timing, giving a steady picture with reasonably straight verticals. If this was not done, line tearing (normally seen at the top of the picture) would occur, as you have mentioned.
Many people use their remote-controlled VCR to change channel on a non-remote TV, which is tuned to its 'A/V' channel. The reason that there is (usually) no noticeable problem, caused by the 'incorrect' line flywheel time constant, is simply because weak signals, ghosting and interference are far less of a problem than they used to be!

Byte an Apple

Dear Sir,
As a computer enthusiast I find the projects for computers the most interesting, but the only problem is I have not yet seen any projects involving the Macintosh (using a 680XX processor). The main reason I am writing is because I am looking for two sorts of projects:
The first one is for a video digitiser for the Macintosh, and the other is for one that would allow me to use the RGB output of a SCART lead with an RGB monitor (TTL RGB).
Andre-John Mas, Brussels, Belgium

There will hopefully be something about Peritel/SCART connections coming along soon. Your other suggestion for Macintosh projects has been passed on to the Design Lab.

Con'Fused' about Fuses

Dear Sir,
I recently decided to check all the 13A mains plugs in the house to ensure that they had the correct rating fuse fitted. What I expected to be a fairly quick job turned out to be very thought-provoking. It soon became apparent that many appliances had 13A fuses when their power ratings were modest, indicating that a 3A or 5A fuse would be preferable. At this point I know what you will be thinking – I have bought 13A plugs which always come with a 13A fuse and not bothered to change to the correct fuse. Well, in a couple of cases I must confess this was true and I replaced the fuses with correcty rated ones. However, in a number of cases the 13A fuse had been correctly fitted as per the manfacturers instructions. Why is it that a 750W vacuum cleaner requires a 13A fuse? One would assume a 5A fuse would be sufficient. I accept that such an appliance will generate current spikes when switched on, but would have thought that a plug fuse was of the anti-surge variety and able to cope with this. (I would be very interested to know if they are of the anti-surge or the quickblow type as your catalogue doesn't say.) If they are of the quickblow type, I wonder why appliances don't have current-limiting devices built-in as it is surely better to have a lower fuse rating protecting you than one which offers much less protection once the device is switched on and running at a far lower current.

A very interesting letter, and one which will interest everybody! The first fact, one which is not immediately obvious, is that the fuse in the plug is intended to protect the appliance's cable from overload. In domestic electronic equipment, which tend to be fairly low-power, there are lower value mains fuses fitted inside the unit or on the back panel. These low-rating fuses are designed to protect the equipment and the user. In addition, some appliances also incorporate thermal fuses.
For equipment such as this, such measures are going to be clearly more effective than the 2 or 3A fuses fitted in the mains plug. Relatively high-powered electrical items (washing machines, vacuum cleaners, etc.) do not tend to have internal fuses; a correctly rated mains plug fuse affords adequate protection. However, many modern products of this type often incorporate electronics which are protected by lower value internal fuses. Despite this, it IS prudent to choose a mains fuse suited to the power rating of your electrical item. Calculating its value is easy; divide the power rating (in watts) by 240 (the mains voltage) to get the current consumption. When you have obtained this figure, select the fuse with the nearest higher rating.
An interesting development (highlighted by the BBC's excellent 'Watchdog' programme) is new legislation concerning the provision of mains plugs. Soon, all mains-powered electrical goods intended for domestic *use must be supplied with ready-fitted (and correctly fused) mains plugs. The correct fitting of these plugs (by a suitably competent person) is the responsibility of the retailer. Perhaps this is why many retailers are now refusing to stock products without moulded-on plugs!*
Next, we turn to your query on the characteristics of mains fuses. Whereas the 20mm glass fuses used in low-powered electronic systems are described as having quick-blow (F) or time-lag (T) properties, detailed in BS4265/IEC127 standards, 1in. UK mains plug fuses, however, are rated differently and are detailed in BS1362 – a different standard compiled for a different application! So to describe a mains plug fuse as being 'T' or 'F' would be both incorrect and misleading.

CW on 2m

Dear Editor,
I would like to say that I have always been impressed with both your catalogue and your magazine.
I have read all the magazines from the first issue, and I consider it the best electronics magazine available.
I welcome the increase to a monthly publication.
I would like to point out a slightly misleading statement in the 1992 Maplin catalogue. On page 323, in the write-up for the Morse Practice Oscillator, it states that to transmit your own messages in Morse you need a class 'A' radio amateur licence. A view shared, it seems, by a great many radio amateurs themselves. However, the statement is not entirely true. It *is* true that you need to have passed the Morse test as well as the RAE examination to gain a class 'A' licence before you can use the HF bands. However, in accordance with clause 2 (1) (c) in the booklet BR6, issued with every licence, the class 'B' licensee is perfectly entitled to use Morse code as a means of communication without having passed the Morse test. The only restrictions relating to class 'B' amateurs are in clauses 2 (2) (a) and 2 (2) (b) which state that they are not allowed to transmit on bands below 30MHz. I have always been fascinated with Morse code and I will be taking the Morse test later this month, but since gaining my class 'B' licence I have found there is little or nothing for us when it comes to this fascinating method of communication, which uses only a very small portion of the available band. It is very often successful when other methods of communications fail because of range, band conditions, interference etc. It would be nice to see some CW kits and projects for the amateur bands above 30MHz to give the class 'B' amateur a similar range of low-cost facilities to those available for class 'A' amateurs. How about it?
Keep up the excellent work.
D B Fisher (G7KDB), South Yorkshire

Thank you for raising this valid point in your letter. However, the new Novice Licence (A), aside from providing the beginner with an easier route into this fascinating hobby, allows the Class 'B' licensee to operate on HF. To gain this privilege, holders of the RAE must simply pass a 5WPM Morse test (as opposed to the 12WPM test that must be passed by would-be Class 'A' operators); the interested individual can then transmit, with some restrictions, on sections of the HF band. This includes the popular 80m band.
You may ask why we are telling you this, after all your letter is primarily concerned with CW operation on 2m. However, while you are absolutely correct in what you say, far more activity can be found on the HF bands which, as an added bonus, provide greater opportunities for DX when the conditions are right (even considering the Novice Licence's 3W power restriction)! In the meantime, it would certainly be encouraging to see (hear?) more CW activity on VHF; it provides the Class 'B' licence-holder with a chance to practise Morse operation 'on the air' – perhaps for that all important Class 'A' or Novice licence?
For information on the Novice licence, contact:
The Radio Society of Great Britain, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE.

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VIDEO PROCESSING SYSTEMS

Part Three by J. A. Rowan

As promised last time we shall now look into what makes up the basic colour television picture signal, and also PAL, in more detail, and how these signals can be processed. The simplest type of video distribution amplifier, which is the simplest class of video processing device, amplifies and buffers the signal and can usually drive from five to twelve outputs. It is just about the only kind of video equipment that does *not* need to know anything about the timing of the signals it carries. Every other video processing device must, at the very least, detect synchronising pulses in order to do its job, and some equipment must completely dismantle the video signal, decode it, digitise it, store it and later recode and output it, having rebuilt it around a totally different set of sync pulses. To do this successfully requires accurate analysis of the frequencies and relative timings of the various parts of a video signal.

Sychronisation

One of the most common tasks in video equipment is that of synchronising one device to the video output of another. This is necessary whenever two sources of video are to be combined, for example when computer generated captions are overlaid onto pictures from a camera. Obviously, when two pictures are mixed or wiped together, every part of one picture must overlay the corresponding part of the other. To achieve this, the timing of one of the signals must be adjusted to match the other exactly. When colour pictures are involved, not only must the sync pulses of the two signals line up, but the phases of the subcarrier must agree to within a degree or two. It is possible to buy a device called a synchroniser that will accomplish this task, but at a cost of many thousands of pounds. Wherever possible, the timing of the video source itself must be varied to achieve synchronisation. All professional video sources, with the exception of certain types of VTR, have this capability, known as 'genlock'. This is not to be confused with the 'gen-lock' used to synchronise computers like the Amiga and Archimedes, which is not quite the same thing, although it basically achieves the same end. Computers normally produce parallel RGB outputs, so subcarrier synchronisation is not involved.

"The timing of one of the signals must be adjusted to match the other exactly. When colour pictures are involved, not only must the sync pulses of the two signals line up, but the phases of the subcarrier must agree to within a degree or two . . . a synchroniser that will accomplish this task may cost of many thousands of pounds."

The most fundamental of processing tasks is the detection of sync pulses and the recovery of separate vertical and horizontal timing references. The sync pulse for composite video is the most negative 30% part of the luminance level (for example see also colour bar signal diagrams from part 2), so it is not too difficult to extract using level-detection techniques. Unfortunately it is not a trivial matter either, since the colour subcarrier can overlap the sync pulse by up to three-quarters of its height, and a video signal does not have a defined DC level. It is necessary, then, to use some form of peak detection to locate the voltage level of the sync pulse tip, and it is advisable to filter out at least some of the subcarrier before attempting to do this. The simplest of sync detectors, shown in Figure 1, combines the action of defining the DC level of the sync pulse tip with level detection. Under no-signal conditions, Q1 is saturated by the base current supplied by R2. Any alternating signal applied to the input will charge C1 through R1 and the base-emitter junction of Q1 on the negative-going edge, and turn off Q1 on the rising edge. With a video signal supplied, Q1 will come out of conduction on the rising edge of the sync pulse and will stay off until the signal again approaches its most negative value, i.e. on the falling edge of the next sync pulse. The combination C1/R1 will discharge somewhat during this time, and the time constant must be large enough that Q1 does not begin to conduct early. To make use of the rather variable Vbe of Q1 in this way, the video signal is usually amplified by about three or four times before being fed to this circuit. Inverted composite sync will appear at Q1 collector.

This sync detector is really very primitive and only suitable for the most undemanding uses. Sync pulses must not be seriously damaged by moderate low-pass filtering to remove the subcarrier. Their rise and fall times (10%–90%) are therefore extended during generation to about 250nS with the timing reference occurring at the 50% point. Any variation of the level at which Q1 switches on will therefore vary the timing of the detected pulse relative to the original video, and this will usually have undesirable results.

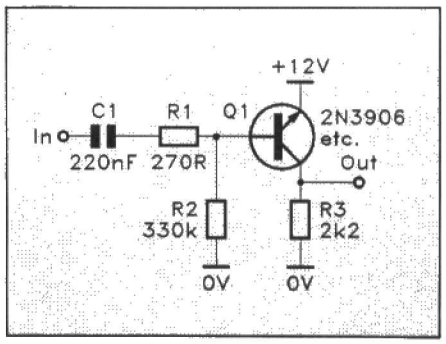


Figure 1. Simple sync separator.

The exact discharge curve of C1/R1/R2, for instance, will depend on the average picture level (APL) of the video signal, and this leads to timing variation with picture brightness. A picture digitised using such a horizontal reference would appear to 'pull' to one side at bright parts of the picture. In addition, sudden large changes of APL in an AC-coupled signal will shift the DC level of the sync pulse tip by anything up to 300mV. Depending on the time constants of the charge and

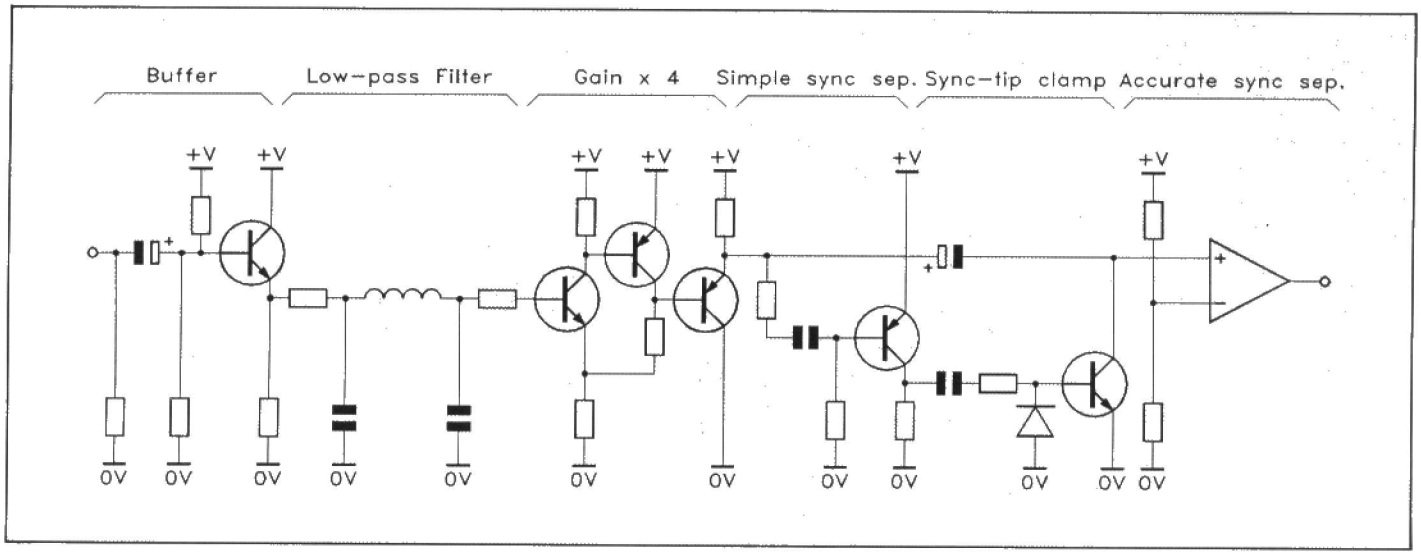


Figure 2. Higher performance sync separator.

discharge of C1, this can cause sync pulses to be missed. The next step is therefore to stabilise the detection level. The simplest way to do this is to clamp the sync tip of the video signal to a known voltage, usually ground, and to then compare the video level to a fixed DC level. Given fast clamping, no disturbance of video level should then affect sync detection. To operate a clamp, however, we need a pulse occurring at the same time as the sync pulse, but that's just what we are trying to generate . . .

The answer is to use our crude sync separator to generate a clamp pulse, which is then used by a second, more accurate sync separator as in Figure 2. A still more sophisticated design (Figure 3) would recognise that any variation in overall video level would still affect the switching point, and so would use a second pulse developed by the simple sync separator to sample the video level of the 'back porch', the name given to the period following the sync pulse before actual active video begins. This sampled value would then supply the reference input of the comparator with a voltage exactly mid-way between the sync pulse tip and the black level by means of a voltage divider, and could maintain the correct sync detection point over a video level variation of at least three to one. This level of sophistication is necessary in order to meet the performance requirements of the broadcast television industry, but not normally for anyone else. Today, most sync separation is likely to be carried out in a single chip such as the National LM1881, which greatly simplifies the task. It should, however, be borne in mind that the performance of such devices may not meet the most demanding of specifications.

"A more sophisticated sync separator would recognise that any variation in overall video level would still affect the switching point . . .This level of sophistication is necessary in order to meet the performance requirements of the broadcast television industry, but not normally for anyone else."

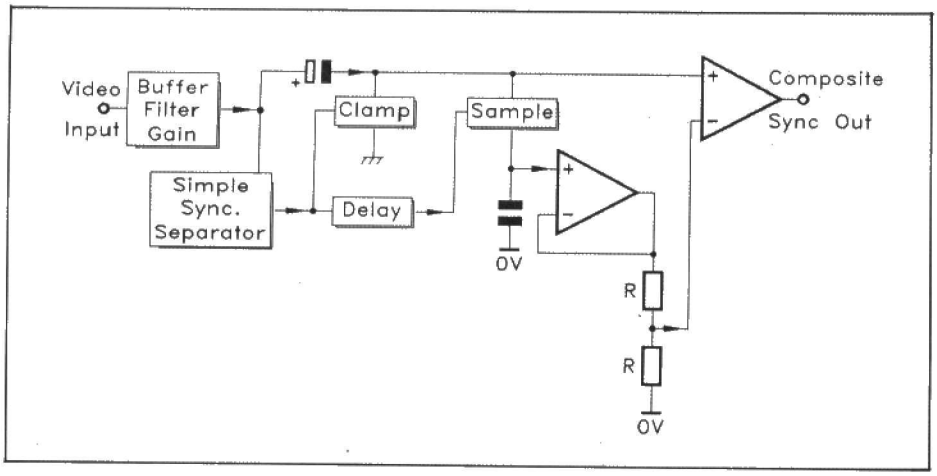


Figure 3. Level compensating sync separator.

Separating Vertical from Horizontal

Having separated the composite sync from video, we now need to recover the separate horizontal and vertical sync pulses from it. The time-honoured method for doing this is with a differentiator to pick out all the leading edges to form the horizontal pulses, and an integrator to locate the longer broad pulses that make up vertical sync. This method will work, and has been used in TV receivers for decades, but in a video processing device it is usually necessary to go further. Mixed in with the differentiated horizontal sync pulses are the edges of equalising and broad pulses that occur half-way between the genuine sync pulses. These can be removed by using all the leading edges of composite sync to drive a non-retriggerable monostable with a period greater than half a line. This will trigger on normal sync pulses throughout active video time, and also on the alternate equalising and broad pulses which correspond to sync. The additional pulses will simply be ignored. Broad pulses can be detected by a 10μS monostable driven by composite sync. If sync is still low at the end of the monostable period, a *broad* pulse has been found. The first broad pulse found can be used to generate the vertical sync reference. If this first broad pulse also coincides with a horizontal sync reference, then *field one* has just started. Most equipment will need to know which field is which.

The next level of complication is reached when noise immunity is necessary. Detecting horizontal and vertical sync and field one is easy when the original video comes straight from a test generator or professional camera. When video arrives along a noisy cable, from a satellite or is replayed from tape, it is likely to be less than perfect. Interference and tape dropout can trigger the sync separator, and sync

pulses may sometimes be missing altogether. It is important that any process critically dependent on sync timing is not fooled by missing or 'extra' syncs. Again, monostables may be used to check the length of alleged sync pulses and to reject any that fall outside reasonable limits. Serious bursts of noise could still get through, however, and an improvement is to only pass pulses that begin close to one line period after the last one. A monostable is not really good enough here, as we need timing stability of about a hundred nanoseconds at the end of a 64μS period. The usual technique is to lock an oscillator to a multiple of the line frequency, and to use a counter and decoder to open a gate for valid sync pulses. If such a pulse is not received, then the counter itself can provide one, and, as long as the majority of true sync pulses are recognised, no harm will be done. This solution is not as extravagant as it may seem, as a digitiser must lock a VCO and counter to input video in order to generate its sample clocks and gates, and it is usually a simple matter to decode some additional pulses for sync validation. Some provision must of course be made for initial lock-up of the VCO, since if validation is insisted upon from switch-on, the system is unlikely ever to find a sync pulse!

There may be a similar need for noise immunity in vertical sync detection, particularly when the source video comes from a video recorder. Almost all types of VTR produce a discontinuity in the video signal close to the vertical sync pulse, and this may upset the detector. A solution used in high performance detectors is to actually count the broad pulses found, resetting the count if one or more is missed and validating a set of exactly five (six in NTSC). The confirmation of a genuine vertical sync signal can, obviously, only come after all five broad pulses have been found, and if a true vertical sync pulse needs to be generated, then it must be done by a phase-locked loop, again normally a counter and decoder. Again this is a practical solution, because a device which digitises and stores video must know on which lines to start and stop, and may require several differently timed field and frame rate pulses. Such a counter will therefore already exist, and must be reset by a vertical reference taken from input video, and the amount of additional circuitry necessary to count the broad pulses is quite small.

Is all this complication really necessary? The answer depends on the application, and whether or not real-time operation is required. For a home computer digitiser, for example, the answer is 'probably not'. The video signal will come from either a camera or video recorder, and either way the user is able to attempt to store a picture as many times as necessary until the result is satisfactory. On the other hand, a timebase corrector or synchroniser must produce an output picture of as good a quality as possible continuously, and a single dropout or interference pulse must not be allowed to corrupt half a field by disrupting the digitising clock.

"Interference and tape dropout can trigger the sync separator . . . It is important that any process critically dependent on sync timing is not fooled by missing or 'extra' syncs . . . monostables may be used (but) serious bursts of noise could still get through however; an improvement is to only pass pulses that begin close to one line period after the last one. A monostable is not really good enough here, as we need timing stability of about 100nS at the end of a 64μS period."

Colour Decoding

The other set of timing information we might require from a colour video signal concerns the colour subcarrier. If we are to decode PAL or NTSC into its components, we must first phase-lock an oscillator to the colour burst (see Part 2) and also, for PAL, determine the V phase switching sequence, usually known as PAL ID. By far the simplest and cheapest way of doing this is to use a TV burst-locked oscillator IC. Simply use a band-pass filter to extract the chroma from composite video, and feed it to one of these chips, and out will come continuous subcarrier and PAL ID, both derived from the input chroma. Some less useful ICs do not produce PAL ID explicitly, but produce a second, PAL switched, feed of subcarrier suitable for V decoding.

This design approach is suitable for the majority of non-broadcast applications, but may not be adequate for use in professional equipment, since the reaction of such an IC to a disturbance in input video is often unpredictable. These ICs expect to receive a continuous video signal with crystal-stable subcarrier frequency and phase, and may not be able to re-lock quickly after a sudden phase change. Another disadvantage of TV ICs is that they are usually designed to work with a 4·43MHz crystal, and a four times subcarrier frequency (17·7MHz) oscillator is more useful for video processing. A final point to bear in mind is that TV ICs often have a short production life, and may only be available for a year or two before being superseded. This is obviously a serious matter if commercial production is contemplated.

A Discrete Colour Decoder

A discrete component burst-locked oscillator requires a phase detector and a voltage controlled crystal oscillator. The colour burst has a phase which changes through 90 degrees on alternate lines, so an error signal cannot be derived from any one burst. Comparison with a continuous subcarrier signal from the VCO will give rise to two different error values, which must be averaged to find the true error. Any non-linear mixer can be used to develop an error signal from the input burst and the VCO output, but filtering is simplified if a balanced synchronous demodulator is used. Various proprietary ICs are available but again, the use of a well-established device such as the 1496 is advisable to ensure long-term availability. Error processing is normally arranged such that the system locks with the demodulating subcarrier corresponding to the $-U$ axis of the video chroma. The output from the demodulator is then a series of alternating positive and negative pulses occurring at the time of the colour burst, and having a long-term average value of zero. A phase error will produce a non-zero average value of a polarity depending on the direction of the error, which is just what we need to control the VCO. Unfortunately, averaging the error by integration will make the system very slow to respond to changes, which is just what we don't need, and in any case, there is little energy in the decoded burst and considerable amplification will be required to drive the VCO. A fast-acting detector must somehow find the mean value of the alternating bursts and immediately apply any error to the oscillator.

The usual way to do this is to sample and hold the alternate positive and negative burst values into two buffers and to average the outputs. Half of any error is therefore immediately available, and although some low-pass filtering is necessary to optimise servo lock speed and stability, this is still a great improvement over the performance of the integrator. In theory, it would be possible for the circuit to lock exactly 180 degrees out of phase, also producing a zero error voltage, but this would be an unstable condition and any variation of error voltage due to noise would cause an increasing value of error which would rapidly escalate and move the decoding phase around to the true, and stable, lock point.

The apparently simple matter of

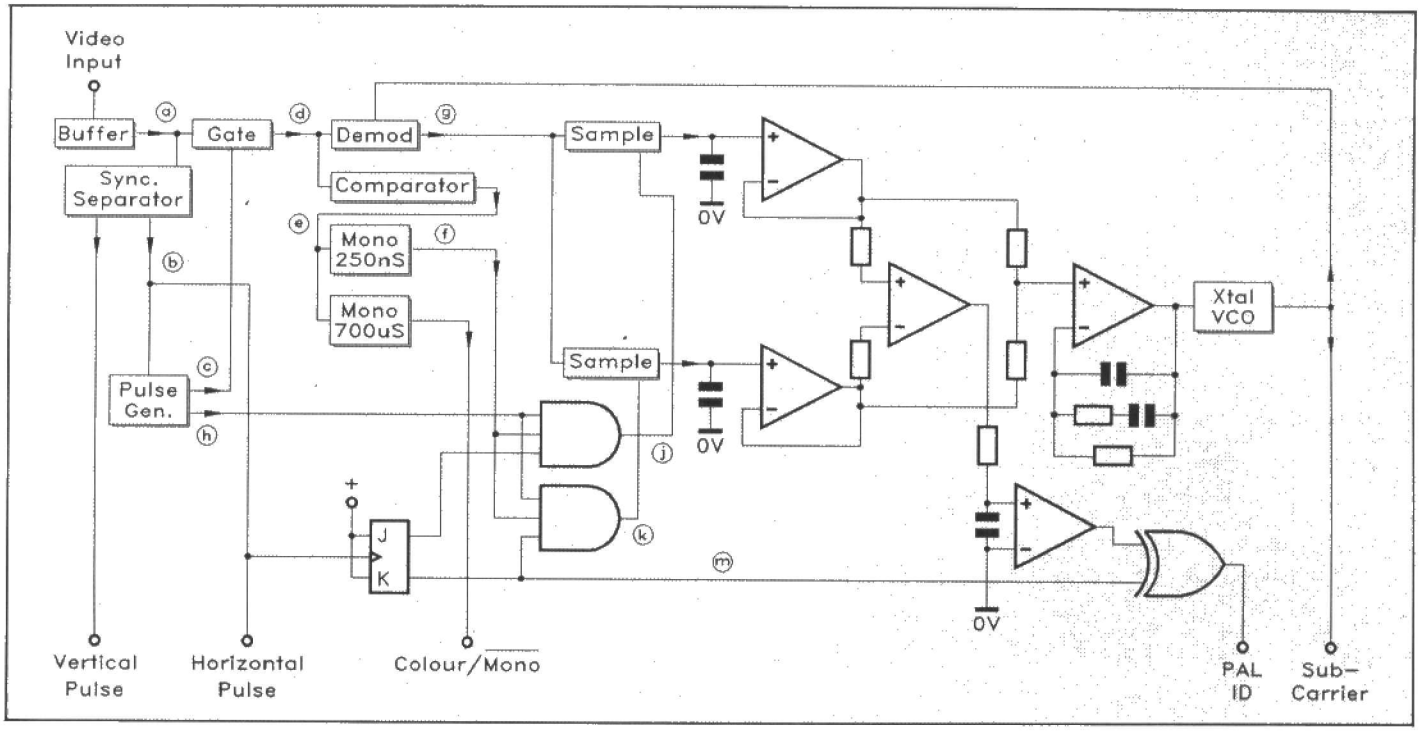


Figure 4. Burst locked oscillator. See Figure 4a for waveforms at points a to m.

PAL ID detection causes endless trouble to manufacturers in NTSC countries, who usually take about three generations of PAL equipment to get it right. The most obvious way of detecting PAL ID is to compare the demodulated burst to a small non-zero DC value. The resulting pulse on alternate lines can be used to set a bistable which is toggled by horizontal sync, producing the 7·8kHz PAL ID square wave. This technique works, but if the two-sampler phase detector is used, there is a more reliable way. A half line frequency square wave must already exist somewhere to route the sample pulse to either sample gate alternately. The polarity of this square wave, relative to video, is unimportant as far as phase detection goes, but if it can be made to correspond to PAL ID then there is no need to generate the latter separately. The relative polarity of the two sampled burst values shows whether the square wave agrees with PAL ID or not, and can either reset the square wave generator if it was in error, or invert the square wave to produce PAL ID if necessary. The latter technique seems less elegant but is actually much more reliable.

An alternative technique relies on 'Bruch blanking'. The colour burst is not present during vertical sync, and some early colour decoders had problems re-locking when the burst reappeared. This led to the burst being blanked for nine lines in each field in such a way as to always have positive V phase on the first and last bursts of a field. The resulting pattern of missing bursts was named after Dr. Bruch, one of the designers of PAL. Some designers have taken advantage of Bruch blanking by using the first burst of a field to set a flip-flop which is then toggled on each line, providing a simple and reliable method of detecting PAL ID. Unfortunately, a small number of video equipment items do not apply Bruch blanking correctly to their outputs, either because the designer did not know about it, or did not feel it necessary. Modern decoders do not generally mind this, and it is only when this equipment is installed with other units that pick up PAL ID in this way that the trouble starts.

Noise immunity may also be necessary in colour synchronisation. It is more of a problem, as the analogue value of a demodulated burst must be utilised immediately, almost before being sure that a true burst even exists. A burst detector is important in most equipment as the system must behave sensibly if fed monochrome video. If such a detector is fast enough in action, then the presence of a burst may be used to enable a short mid-burst sample pulse, the sample not occurring if the early part of the burst was not found. This kind of detector must operate on the original 4·43MHz burst, as it must work regardless of whether or not the subcarrier oscillator is correctly locked.

PAL ID detection must also be made noise-immune, but again with a reasonably quick response to genuine phase changes. VTR edits can be made on some equipment which allow a change in PAL ID to occur around vertical sync. This will cause most monitors and colour TVs to display anything from a few lines to a whole field of video with the wrong PAL ID, and therefore the wrong colours, so-called 'colour flashing'. A timebase corrector should be capable of identifying and correcting the fault before active video actually starts, i.e. within, at most, fifteen lines of the first wrong burst appearing. Any disturbance of the burst-locked oscillator itself should also have disappeared by this time. On the other hand, a false indication of wrong ID caused by a drop-out should not be able to invert PAL ID for one or two lines during active video. It is here that the two-sample method of detecting PAL ID becomes simpler, in that an R/C/comparator circuit can be used to maintain ID sequence until, say, four lines with the wrong ID have occurred. Using the alternate burst threshold technique, it would be necessary to use a counter and some extra logic to achieve the same response. The Bruch blanking technique for detecting PAL ID only operates once per field, and is therefore very vulnerable to noise. It should only be used with clean and stable input video, for example in a genlock circuit.

Putting all this together, Figure 4 shows an outline diagram of a burst-locked oscillator. This is a fairly general-purpose building block which might be used in a PAL decoder, timebase corrector or digital effects unit, and might appear again as part of the genlock module. These days, most of the logic used would be in the form of PLDs/PALs(careful)/GALs but is shown here in discrete form for clarity. Monostables are shown in two places, again for clarity, but counters and synchronous logic would improve reliability. Parts of the circuit will vary according to application. Input video may be crystal-stable, as in a genlock circuit, or varying wildly in timing as from a VHS VTR. The sync separator shown may be of varying complexity and the block marked 'Pulse generator' could be anything from a couple of dual monostables up to a sync-locked VCO and horizontal and vertical divider chains. Here only two pulses are required, the burst gate and narrower burst sample pulse. Where a large

number of different pulses are needed a useful technique is to drive a counter from a VCO of 10–15MHz and supply the count as an address to a PROM. The PROM may be programmed to produce arbitrarily complex pulse trains, and this technique is often used in sync pulse generators. Note that to generate horizontal rate pulses such a PROM needs to be fast, though a standard EPROM may be used to generate vertical pulses.

Actually early colour receivers, especially the 'hybrid' variety (meaning also having valves to handle the high deflection voltage signals etc.) of say 20 years ago did, on the whole, possess discrete component colour decoders and the odd IC only appearing for some mundane logic function. What used to occupy 30 square inches or more of board space is nowadays packed into one IC, and more besides.

A Factor of Eight

One last timing aspect of PAL that I will touch on is the 'eight-field sequence', which refers to the fact that the smallest number of fields to contain an integral number of cycles of subcarrier is eight. A timebase corrector which decodes PAL and digitises YUV signals can handle a wrong PAL ID sequence without difficulty, and some will even correct a wrong field1/field2 sequence. Machines that digitise a composite PAL video signal are much more fussy, and this is the type of timebase corrector that must be used with direct colour VTRs. Not only must field and PAL ID sequence be correct, but there must not be a large change in subcarrier phase between one field and the next. This means that edits made on direct colour VTRs can only safely be made at points eight fields apart, and circuits must exist which can detect these points.

"We are now into a rather dodgy area. Field identification is trivial, PAL ID not much more difficult to determine, but correct identification of an eight-field sequence is not easy . . . Life became much easier when the camera manufacturers started to cheat and add a peak-white-level pulse near the beginning of field 1 of the eight."

We are now into a rather dodgy area. Field identification is trivial, PAL ID not much more difficult to determine, but correct identification of an eight-field sequence is not easy. The only difference between two timing points four fields apart is the phase of subcarrier, and we must say that one such point constitutes the eight-field boundary and the other does not. We actually need to measure the phase of subcarrier at a particular instant, or at least discriminate between two values 180° apart. This would be much easier if one point was near the positive peak and the other near the negative peak, and in an attempt to simplify the problem, the EBU specified that the eight-field boundary should be defined by U axis burst subcarrier having a phase of zero degrees at the beginning of the first broad pulse of field 1 of the already-defined four-field sequence.

Life became much easier when the camera manufacturers started to cheat and add a peak-white-level pulse to an otherwise blank vertical interval line near the beginning of field 1 of the eight. This was far easier to detect and soon became a standard, and made eight-field editing much more reliable. Actually, very little equipment needs to detect the eight-field sequence, as it is only important in editing with direct-colour VTRs, but it is important to

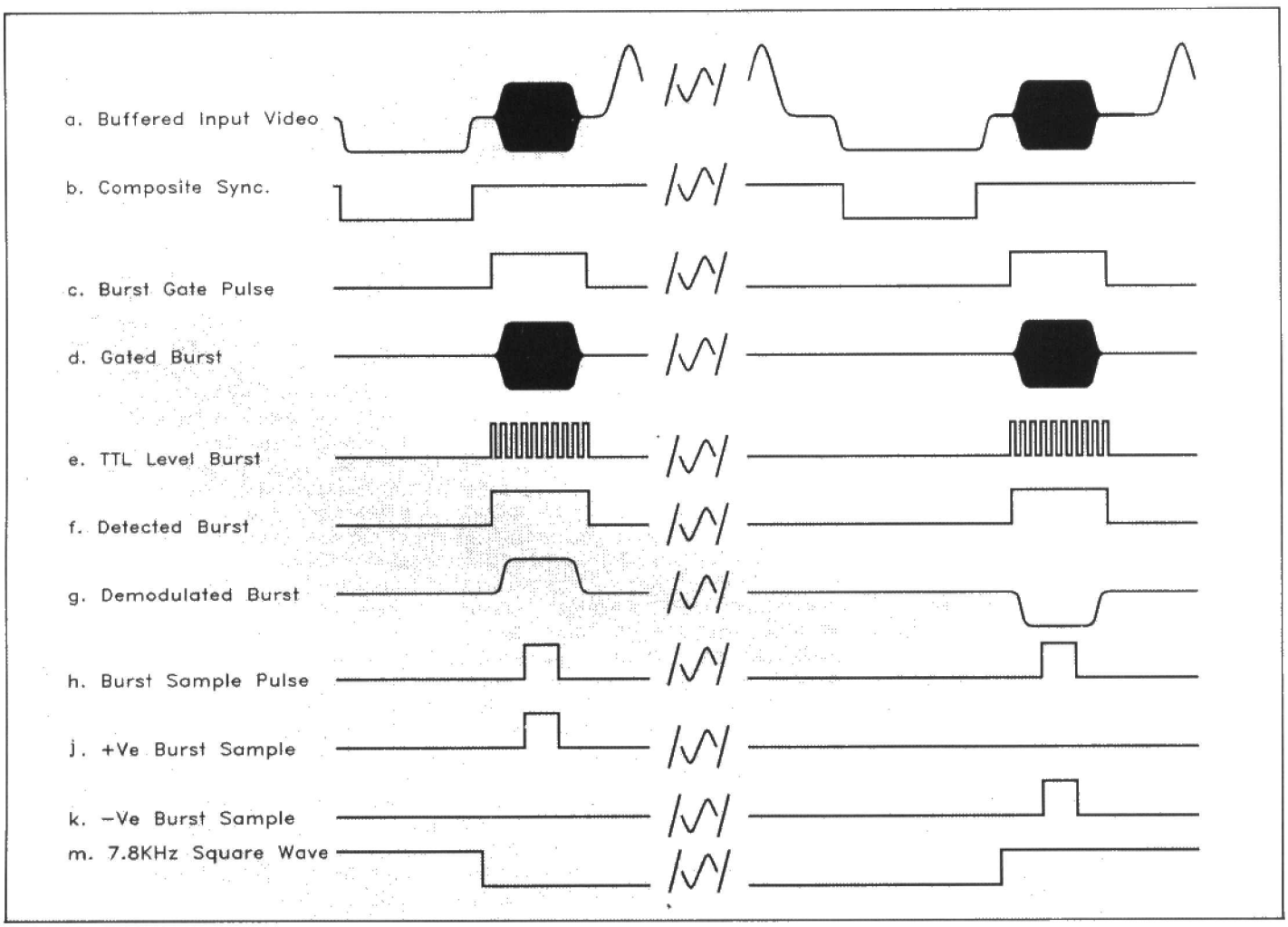


Figure 4a. Waveforms.

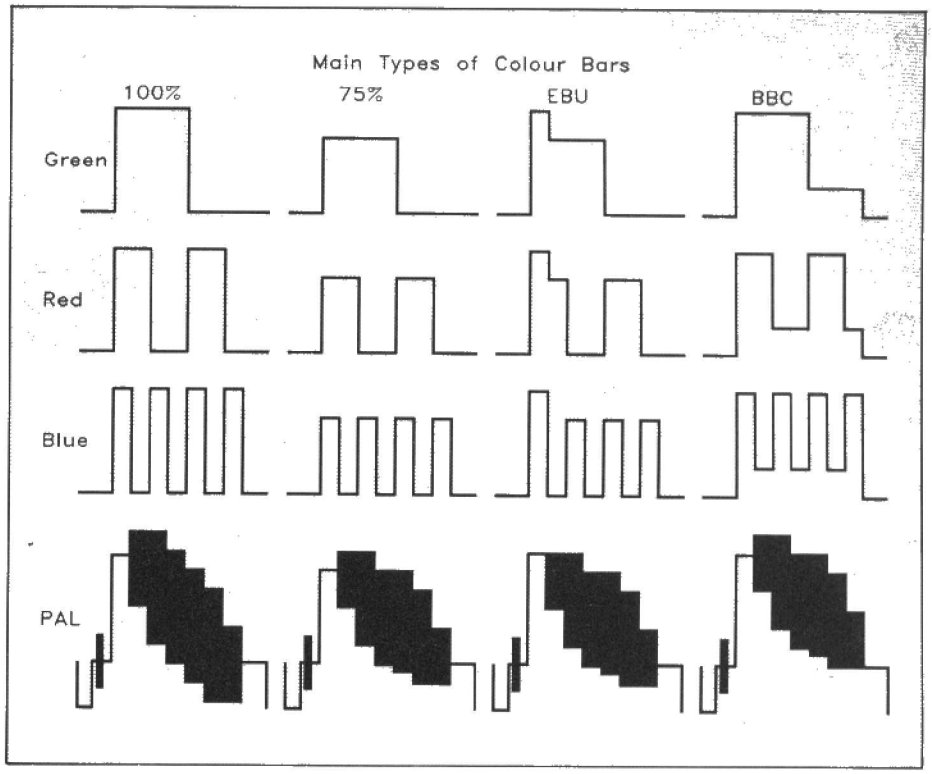
know of its existence if only to de-mystify yet another piece of video jargon.

Next month we will move on from video signals to look at a variety of commercial video equipment, including most types of VTR, and at the problems which can arise when complete systems are assembled.

Appendix

The most common colour test signal is one of the various types of colour bars. Originally intended as a built-in test waveform for colour encoders, colour bars soon came to be used for checking most types of equipment, and to provide a level reference for equalising transmission lines and VTRs. If a problem with a line or processing unit is suspected, there are other signals that will allow more accurate fault diagnosis, but bars provide a quick general check. Colour bars are easy to generate in RGB form, being basically three outputs of a binary counter. The clock needs to be about 6·4μS, synchronous with horizontal blanking so that the white bar starts at the right time. A simple two- or three-gate logic oscillator is often used, as timing stability is not too important and it is easily gated using a blanking signal. A shorter clock period is sometimes used to provide a second white bar after the black one. This allows both edges of the picture to be examined easily to measure blanking timing. Primitive colour bar generators, such as those built into non-broadcast cameras, simply buffer the logic outputs before feeding them to the coder, while more professional generators use the logic signals to switch well-defined current sources to provide stable and accurate RGB levels.

Several varieties of colour bars exist, favoured by particular organisations. 100% bars are the simplest, consisting of all possible combinations of the maximum and minimum possible RGB values. This is a fairly 'unnatural' signal in that the colour saturation of normal pictures rarely achieves 100% levels. Not all video equipment is designed to handle 100% bars, though all true broadcast equipment should. These bars are used extensively by the British commercial broadcasters but are not in common use elsewhere. 75% bars are simply a scaled-down version of 100% bars and are rarely seen in Europe, but form part of the standard EIA bars used in NTSC countries. Their main disadvantage is the lack of a peak white reference, and EIA bars contain a separate 100% white block. EBU (European Broadcasting Union) bars are, as you might expect, fairly common throughout Europe. EBU bars are simply 75% bars with the white bar raised to 100%. BBC bars, used by the BBC and almost nobody else, were designed to avoid problems with sync pulse detection circuits in the early days of colour. All modern sync separators filter at least some of the chroma out of composite video before level detection, but those that were around before colour existed could not be expected to do so and BBC bars were invented to avoid false triggering on chroma information well below black level.



These variations are still fairly easy to generate, as in EBU bars the white bar and in BBC bars the black bar are special cases, and the states of R, G and B being all high or all low respectively can be detected in order to modify signal levels. For example, EBU bars can be made using a generator for 75% bars, with an extra 25% added to luminance when R, G and B are all present.

In the subcarrier modulators of a PAL coder, the resulting AM signals are first scaled before being added to luminance. The final subcarrier level must be high enough to allow a useful signal-to-noise ratio to be achieved, but as low as possible to avoid over-modulation of the RF carrier in transmitters and VTRs. U and V subcarrier levels are scaled differently so that at their maximum levels they reach the same peak video level. As a result, the chroma levels of the 100% yellow and cyan bars reach almost exactly the same levels, as does the chroma of the red and blue bars. Since the other types of bars are linear variations of 100% bars, this is also true of them as well. In addition, in all but BBC bars, the bottom edge of chroma of the green bar is almost exactly at black level (actually a few millivolts below), while the same is true of the red and blue BBC bars. Finally, in 75% and EBU bars the top edge of chroma of the yellow and cyan bars is almost exactly at peak white level. These properties make it fairly easy to adjust U and V levels in coders and other equipment reasonably well using just an oscilloscope or waveform monitor.

More accurate measurements of colour composite video require a specialised test instrument, the vectorscope. This is basically a colour decoder with the U and V outputs displayed on the horizontal and vertical axes of a cathode ray tube. A graticule on the CRT has small rectangular boxes marked around the points corresponding to the six coloured bars of colour bars. Black and white, having zero levels of U and V, appear at the centre of a vectorscope display. A PAL vectorscope does not normally switch the V phase of the signal it monitors, so in fact there will normally be twelve dots visible with a colour bar input. More sophisticated vectorscopes allow PAL switching to be turned on to check that the six normal and six V-inverted dots overlay exactly. A full and detailed description of the uses of the vectorscope is beyond the scope of this article, but with experience it is a very useful tool, and vital for all but the most casual colour video work. Unfortunately, it is also extremely expensive.

Instruments for monitoring YUV video obviously do not need to decode it, but the U/V display is still of use, and most units can produce the 'vectorscope' type of display. A combined display of Y, U and V can also be compared to a graticule for a quick 'go/no-go' check. Colour bars are still widely used as they contain simple combinations of R, G and B.

Another signal commonly used in testing composite colour equipment has the standard monochrome pulse and bar but with an extra pulse added.

Continued on page 70.

MODERN BRIDGE CIRCUITS

Part 3 by Ray Marston

Ray Marston concludes his study of modern bridge circuits by looking at 'special' types, and at C and R substitution boxes.

The first two parts of this series looked at the Wheatstone resistance-measuring bridge and its derivatives in depth, and also at precision L-C-R bridges. This month's concluding part looks at a variety of less well known 'special' types of bridge, including easily built, resistance-matching and ratio-matching types that enable resistors to be matched or duplicated to within ±0·003%.

Special Bridge Circuits

In addition to the types of DC and low-frequency AC bridges already described, there are three others that are of special value. The first of these is the transformer ratio-arm bridge, which is shown in basic form in Figure 26. The value of this bridge's ratio arms (shown as switch-selectable at 0·1/1, 1/1, or 10/1 in this example) depends entirely on the transformer's turns-ratios, and can easily be wound with a precision better than 0·01%. The value of an unknown (x) impedance can be balanced against that of a standard either by varying the value of the standard or the value of the ratio arms. Resistors or capacitors can be balanced against each other by placing them on opposite sides of the bridge as shown, or a capacitor can be balanced against an inductance by placing both components on the same side of the bridge.

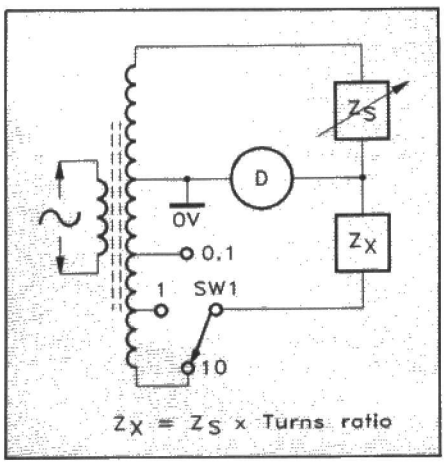


Figure 26. Simple transformer ratio-arm bridge.

Another important bridge is the DC resistance-matching type; Figure 27 shows a simple version that enables resistors to be matched to within ±0·1% or better. Two basic principles are involved here; the first is that if R_A and R_B are exactly equal, the value of R_{MATCH} will precisely equal that of R_S at balance; the second is that if R_A and R_B are equal they will generate exactly the same output voltage whichever way they are connected across the supply. With this second principle in mind, R_A and R_B are joined by 500Ω multi-turn pot RV_1 and are connected to the DC supply via biased polarity-reversal switch SW_1.

To use this resistance-matching bridge, first fit R_S and R_{MATCH} in place, noting that R_{MATCH} is, for simplicity, shown as being made up of a fixed (R_{M1}) and a variable (R_{M2}) element. With the DC supply connected, a meter reading should now be available; if necessary, trim R_{M2} and RV_1 to bring this to a sensible level; now repeatedly toggle SW_1 and trim RV_1 until identical meter readings are given in either toggle position. That completes the R_A-R_B adjustment. The value of R_{MATCH} should now be trimmed (via R_{M2}) to bring the meter reading to zero, at which point R_S and R_{MATCH} are matched. Note that, after RV_1 has been initially set, it should rarely need readjustment, and that the circuit's 'matching' fidelity is limited to ±0·1% only by the balance-detection meter's sensitivity.

When building a resistance-matching bridge, or when matching resistors, low-temperature-coefficient resistors should be used, and these should never be physically touched during balancing/matching operations. Figure 28 helps make this point clear by listing the typical temperature coefficients of various types of modern resistor. Note that when using

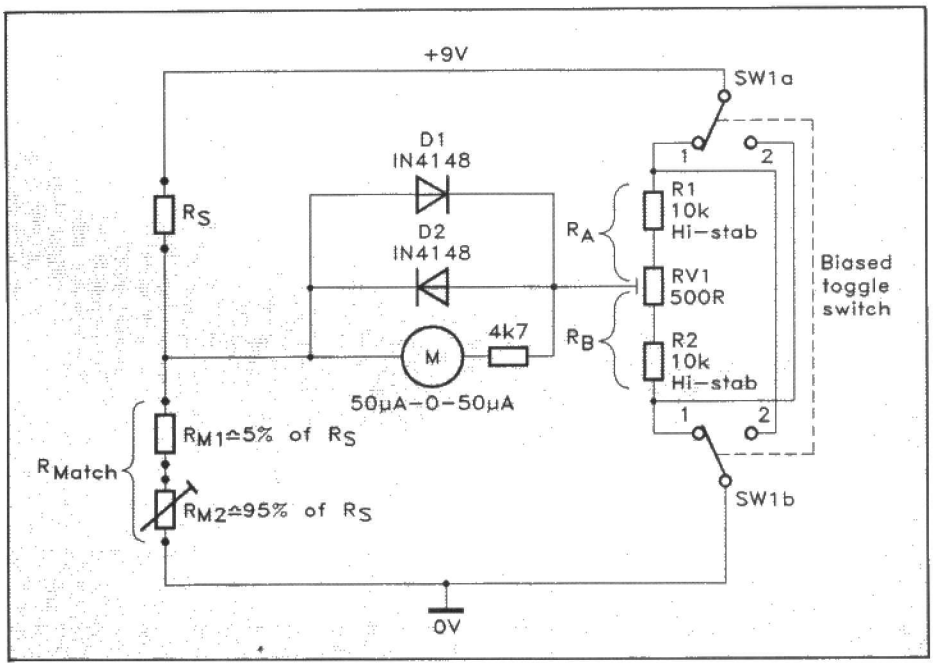


Figure 27. Simple resistance-matching bridge, gives matching within ±0·1%.

Resistor Type	Typical temperature coefficient	
	±ppm/°C	±%/°C
Carbon film	300–1000	0.03%–0.1%
Thick film metal	100–300	0.01%–0.03%
Metal film	50–100	0.005%–0.01%
Precision metal film	15–50	0.0015%–0.005%
Vitreous wire wound	75	0.0075%
Precision wire wound	5–15	0.0005%–0.0015%

Figure 28. Typical temperature coefficients of modern resistors.

the bridge the R_{MATCH} value can be trimmed (to make it equal R_S) by using series resistance to increase its value or shunt resistance to reduce it.

A Precision Resistance-Matching Bridge

Figure 29 shows a precision resistance-matching bridge that incorporates a meter-driving DC differential amplifier that gives such high balance-detection sensitivity that resistors can be matched to within ±0·003%. This bridge also has a facility for indicating, on RV_1's calibrated scale, the out-of-match error of R_{MATCH} as a percentage; this scale spans ±0·5%, ±0·05% and ±0·005% in three switch-selected ranges.

To set up this bridge initially, fit R_S and R_{MATCH} in place, connect the op-amp's output to an external multimeter, and connect the supply via SW_4. Now close SW_3 and trim the op-amp's 10k SET BALANCE control for zero reading on the meter's most sensitive DC current range; release SW_3. Now set RV_1 to mid scale and, with SW_2 initially set to its 'x1' scale, start toggling SW_1 and trim RV_2 (and if necessary, R_{M2}) to find a setting where identical meter readings are obtained in both toggle positions; as RV_2 nears the balance point, increase balance sensitivity via SW_2, until eventually a perfect balance is obtained on the 'x0·01' range. That completes the initial setting up procedure, and R_{MATCH} can then be matched to R_S by trimming R_{M2} for a zero reading on the meter. Once the circuit has been initially set up as described, RV_2 and the op-amp's SET BALANCE control should only rarely need readjustment, and in all further 'matching' operations the following procedure can (after making a brief initial check that the meter and toggle balances are correct) be used:

Fit R_S, R_{MATCH}, and the external multimeter in place. Turn SW_2 to the 'x1' position, and switch the bridge on via SW_4. If R_{MATCH} is within ±0·5% of the R_S value it should now be possible to set the bridge to a null via RV_1; if necessary, trim the R_{MATCH} value until a null can be obtained. At null, read off the R_{MATCH} error on the RV_1 scale (see Figure 29), and then make the appropriate error correction; to increase the R_{MATCH} value by a fixed percentage, add a series resistor with a value of:

$R_{SERIES} = (R_{MATCH}/100) \times \%$ error.

To reduce the R_{MATCH} value by a fixed percentage, add a shunt resistor with a value of:

$R_{SHUNT} = (R_{MATCH} \times 100)/\%$ error.

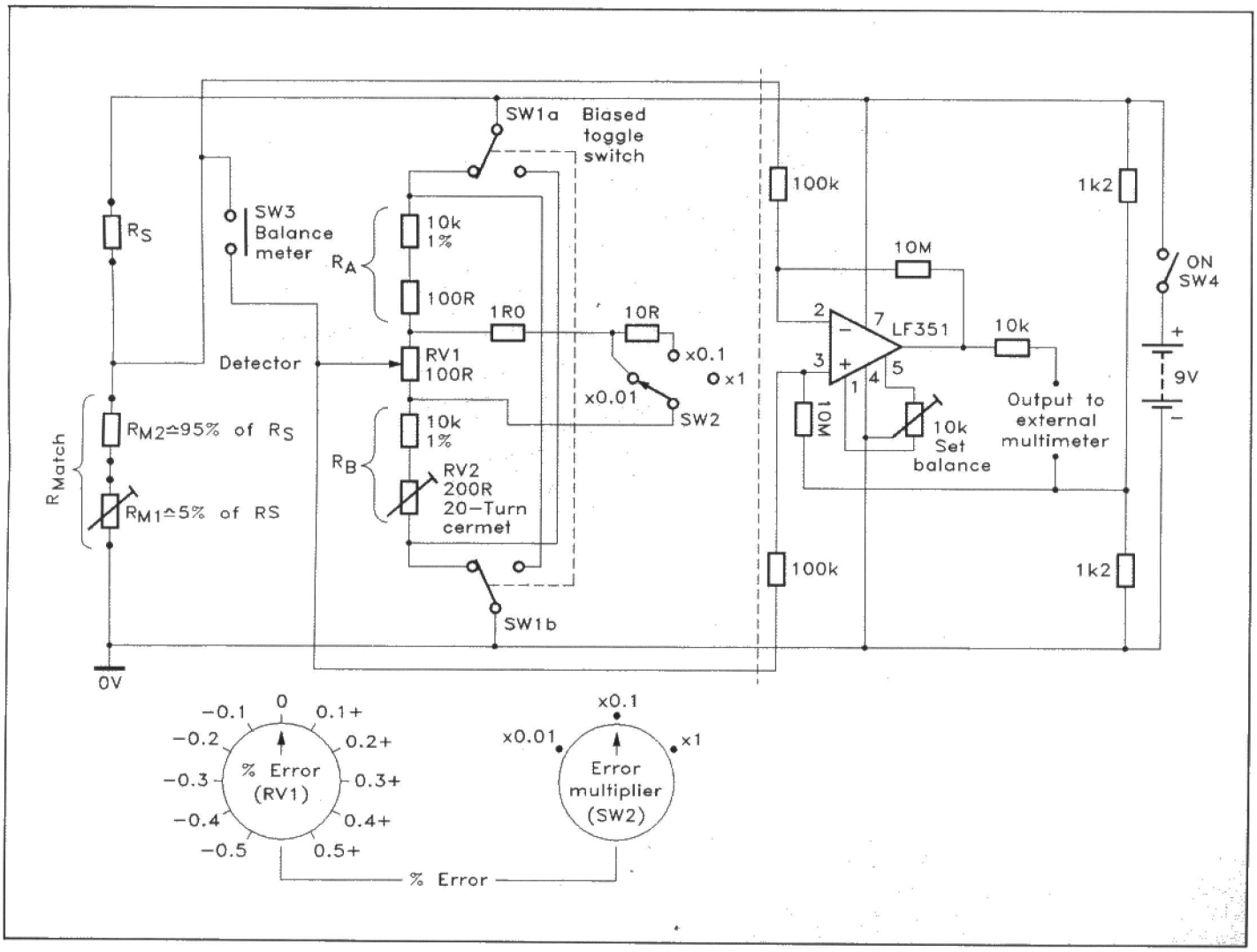


Figure 29. High-precision resistance-matching bridge, gives matching to within 0·003%.

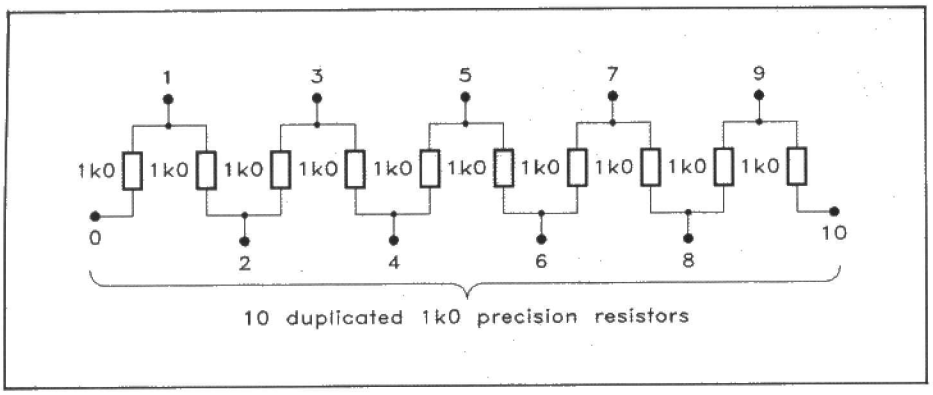


Figure 30. This matrix of 1k resistance totals 10k when series connected, or 100Ω when parallel connected.

Thus, a 1000Ω (nominal) resistor can be increased by 0·03% by adding a 3Ω series resistor, or reduced by 0·3% by adding a 330k shunt resistor. Once a good match has been obtained on SW_2's 'x1' range, repeat the process on ranges 'x0·1' and 'x0·01' until the match is adequate. An alternative to this technique is to simply leave RV_1 in its 'mid scale' position and trim R_{MATCH}, via R_{M2} to obtain a null on all ranges of SW_2.

Resistor-Matching Bridge Applications

A precision resistor-matching bridge has several useful applications in the electronics laboratory. One of these is the duplication of precision resistors values, and Figure 30 shows an example of how this facility can be put to good use. Here, ten duplicates of a precision 1k0 resistor are so wired that they can easily be used in series, to act as a resistance that increases in 1k0 steps up to a maximum of 10k, or in parallel, to act as a resistance that decreases in steps down to 100Ω. Note that as more and more resistors are wired in parallel or series, their ±0·003% duplication errors average out and diminish, so that the precision of the final 10k series or 100Ω parallel resistance is equal, for all practical purposes, to that of the original 'master' resistor. The actual value of 'summed' duplication error is equal to the original error divided by the square root of the number of summed resistors (10), and equals 0·001% in this case.

Another important resistor-matching bridge application is in the creation of a precision ratio-matching bridge of the type shown in Figure 31. Here, 14 resistors are duplicated from a 1kΩ (nominal) master and wired together to create a three-ratio (10/1, 1/1, and 1/10) divider. The fact that these resistors are all precision-matched to within ±0·003% ensures that the ratios are intrinsically defined with great precision, the actual precision being ±0·002% on the 1/1 range and ±0·005% on the 10/1 and 1/10 ranges. This bridge can itself be used to produce direct or decade multiple or sub-multiple duplicates of a master resistor. If the bridge is used with a sensitive null detector that gives a duplication precision of 0·003%, the overall precision of duplication is ±0·005% on the 1/1 range, and ±0·008% on the 10/1 and 1/10 ranges.

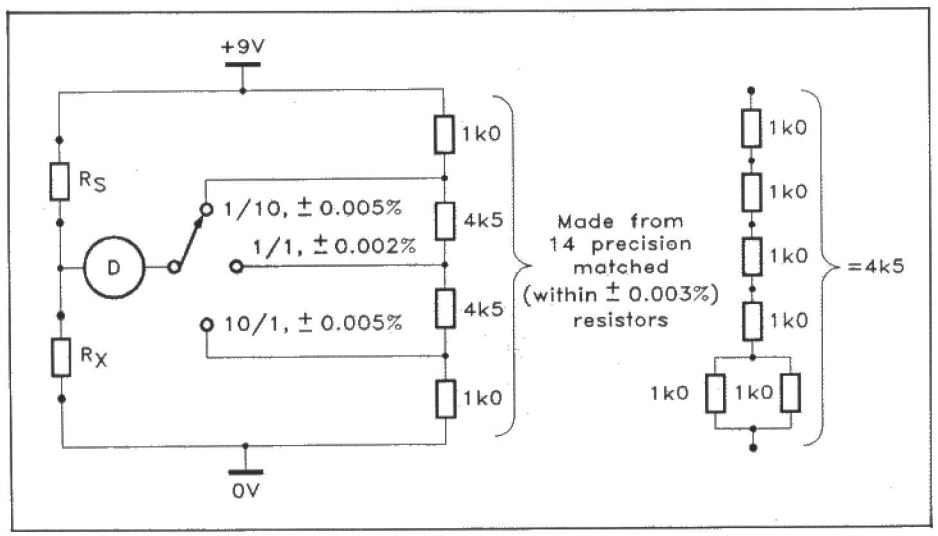


Figure 31. Precision ratio-matching bridge.

'R' and 'C' Boxes

An obvious application of the Figure 31 circuit is in matching the range and ratio arms of conventional bridges, to enhance bridge precision. Another is in generating high-precision resistors for use in decade 'R' boxes. Figure 32 shows a 3-decade 'R' box that spans 0 to 99·9k in 100Ω steps, with 100k over-ranging available via SW_4. This type of circuit can be generated from a single precision reference (1k0 in this case), and has a

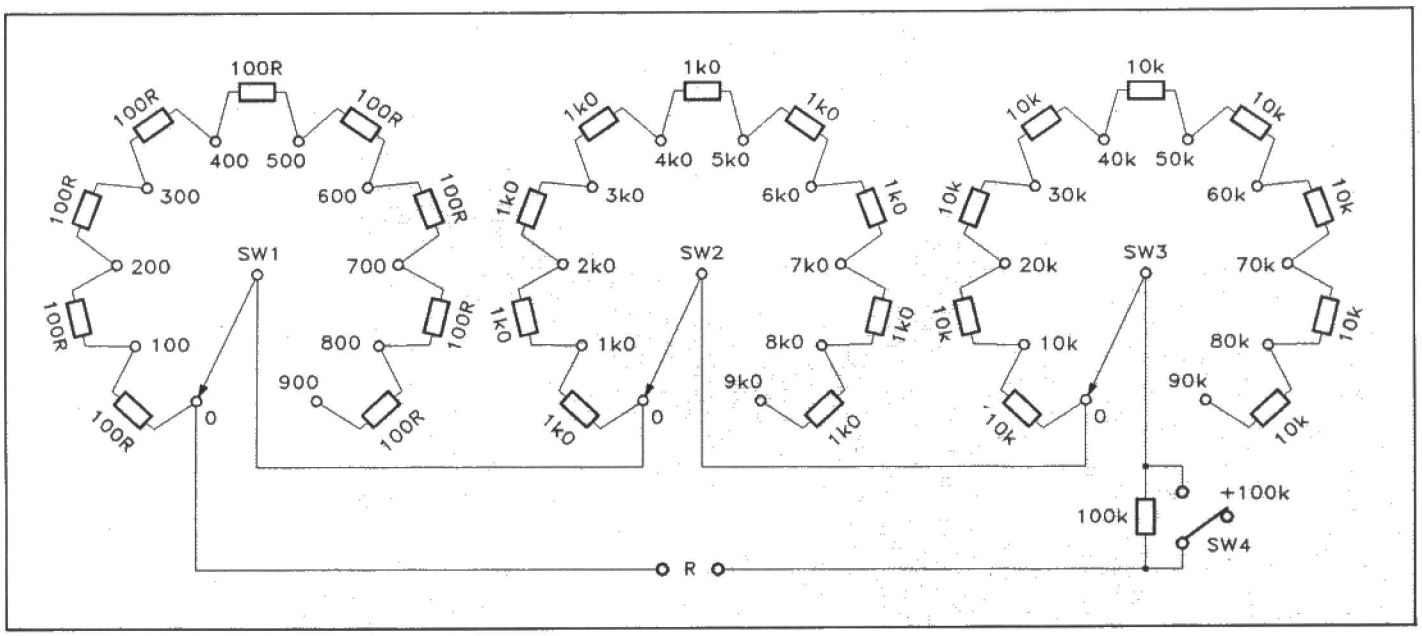


Figure 32. 3-decade 'R' box spans 0 to 99·9k in 100Ω steps.

multitude of applications in the laboratory, including those of calibrating bridge scales and finding resistor values by substitution.

A useful companion to the 'R' box is the multi-decade 'C' box. In these, capacitors are either selected individually or are connected in parallel to make up specific values. Figure 33 shows, in tabular form, one possible way of making a single-decade (0 to 9nF) unit, using only four basic capacitors (the 5nF value can be made by padding up a 4n7F type). Note that three capacitors must be connected in parallel to make up the box's 9nF value, so this design calls for the use of a 3-pole 10-way switch.

Figure 34 shows the table and practical circuit of an alternative design of 0 to 9nF 'C' box which uses five capacitors but only a 2-pole 10-way switch. Since switch wafers are considerably more expensive than nF capacitors, this is an economic design. Two extra boxes of this type, designed to give 10nF and 100nF steps, can easily be built and wired in parallel with it, to form a 3-decade unit that spans 0 to 999nF in 1nF steps.

A Potentiometric Voltmeter

Another important application of the precision resistor-matching bridge is in aiding the creation of a potentiometric voltmeter. This instrument enables DC voltages to be measured with such good precision that it can be used to calibrate 3½ and 4½-digit digital voltmeters. Figure 35 shows the basic circuit of such a voltmeter, which operates as follows:

The Figure 35 circuit consists, in essence, of a precision calibrated 110k variable potentiometer (RV_2) that is energised with 11·000V DC, derived via a stabilised power supply unit and the RV_1 'fine trim' control; 0·1mV is thus generated across each ohm of the pot, which is accurately calibrated in terms of its output voltage. The unit is used in conjunction with a precision voltage reference, which in the diagram takes the form of a Weston 1·0181V 'standard' cell. In use, the pot is first set to read '1·0181V, and SW_1 is then moved to the CAL position and RV_1 is trimmed to give a zero or null reading on the meter; under this condition the pot output and standard cell voltages are equal, and precisely 11·000V are applied across the pot. The external DC test voltage (which must be no greater than 11V) is then connected in place, SW_1 is set to the USE position, and the pot is adjusted to give a null on the meter, at which point the voltage value can be read off directly on the pot scale. Note that zero current is drawn from the test voltage at null. Voltages greater than 11 can be measured by feeding them to the instrument via a precision attenuator.

Figure 36 shows the practical circuit of the 'pot' section of the above instrument. In this, there is 110k of resistance connected into circuit at all times, and 1V is generated across each

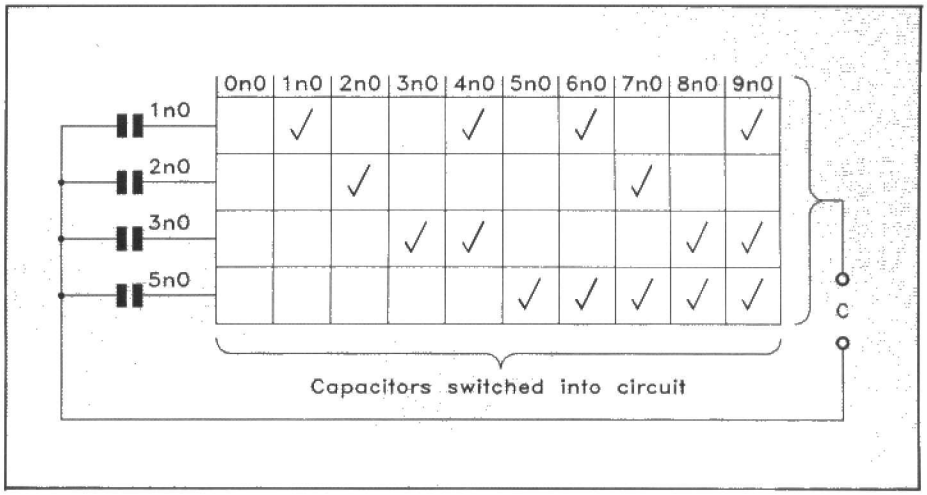


Figure 33. This basic 0 to 9nF decade 'C' box uses 4 capacitors and a 3-pole to 10-way switch.

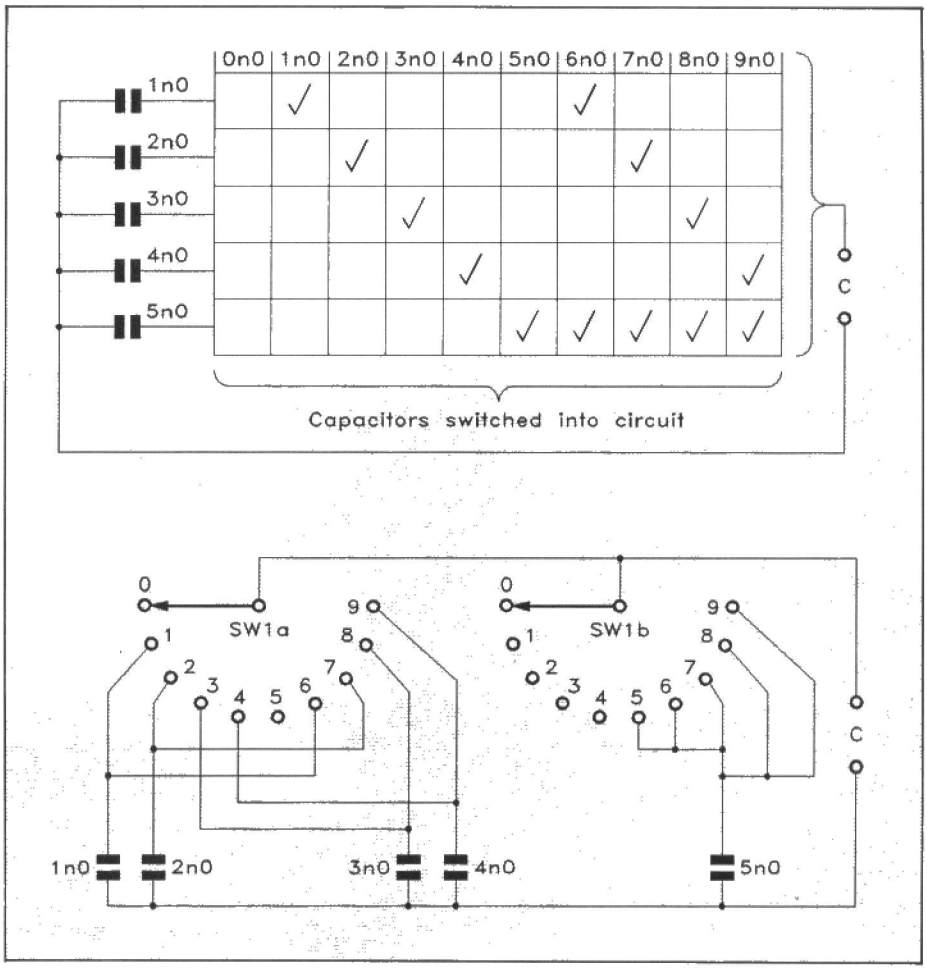


Figure 34. This 0 to 9nF decade 'C' box uses 5 capacitors but only a 2-pole to 10-way switch.

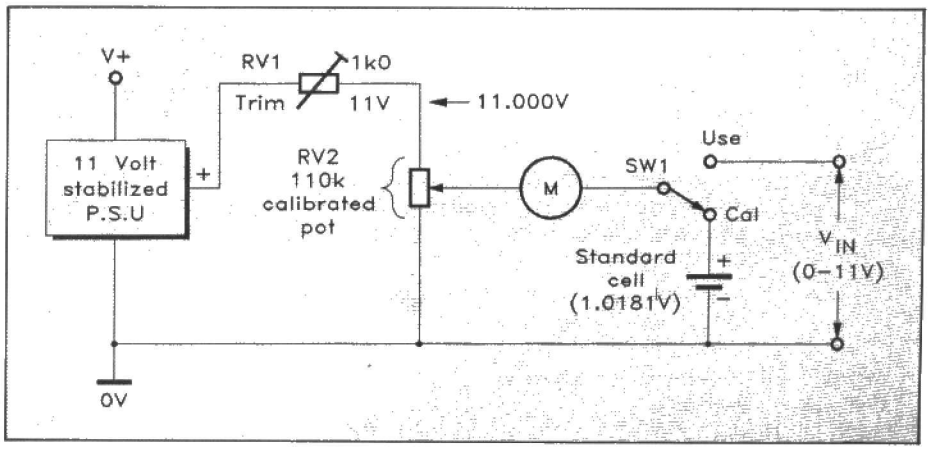


Figure 35. Basic potentiometric voltmeter circuit.

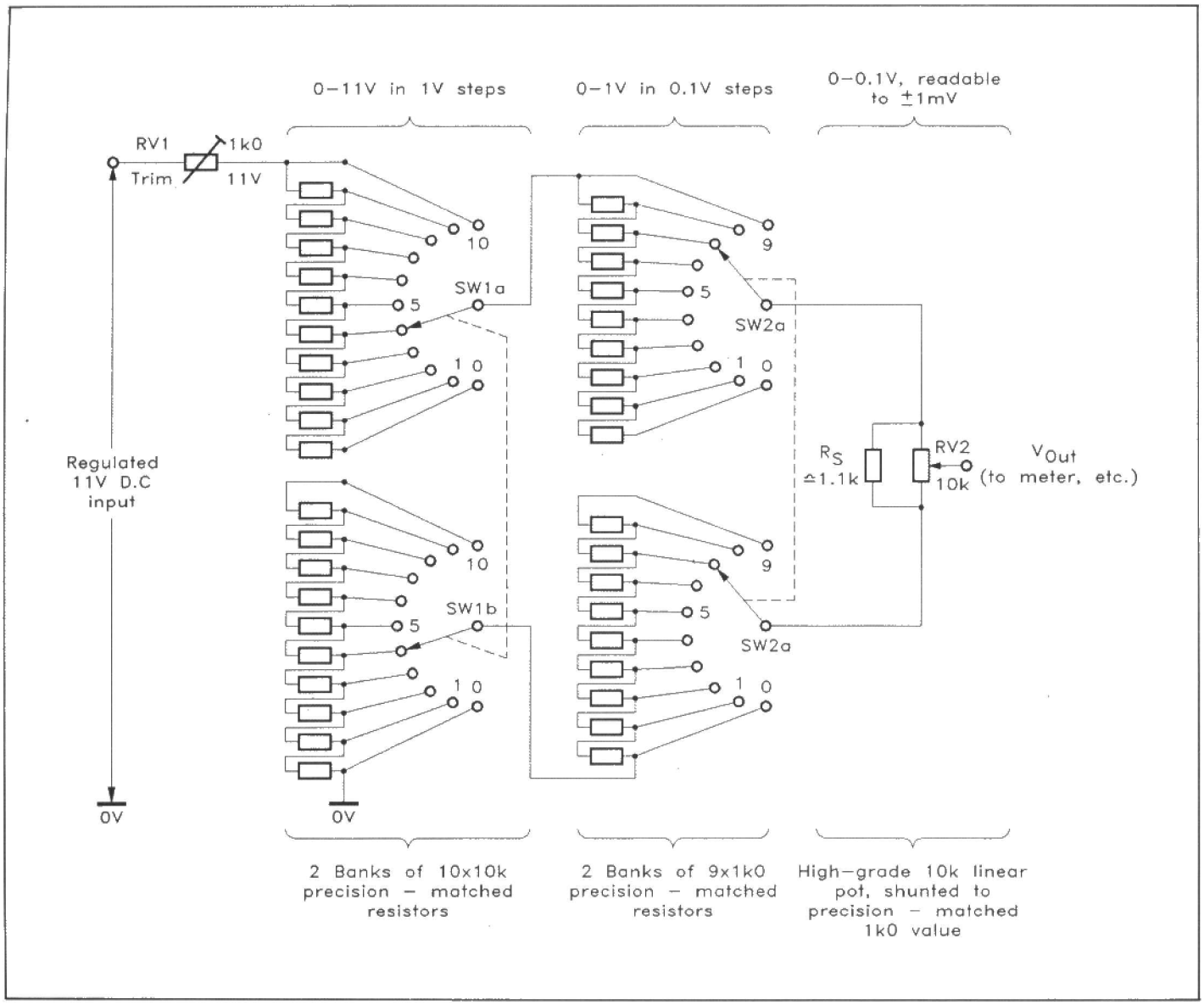


Figure 36. Precision potentiometric voltmeter, set to read 4·750V, has basic accuracy of ±0·005%, ~1mV.

active 10k resistance block when the pot is energised with 11V. Thus, with SW_1 in position '4' as shown, +4V appears on the common terminal of SW_{1b} and +5V on that of SW_{1a}; these voltages are applied to the SW_2 resistor network which, with SW_2 in position '7', gives an output of 4·7V to the bottom of RV_2 and 4·8V to its top. With RV_2 set to mid scale, the unit thus gives an output of 4·750V when the controls are set as described.

The Figure 36 circuit can only read voltages to within the nearest 1mV, so the initial calibration reading must be set to 1·018V when using the standard cell. Note, however, that a further decade of readings can be added to the circuit by replacing RV_2, etc, with a duplicate of the SW_2–RV_2 related circuitry (i.e., all the circuitry to the right of SW_1), but with all component values reduced by a factor of ten. This modification enables the unit to read voltages to within the nearest 0·1mV, and to be initially calibrated to 1·0181 volts. Note that all resistors must be precision-matched against a single 10k reference resistor.

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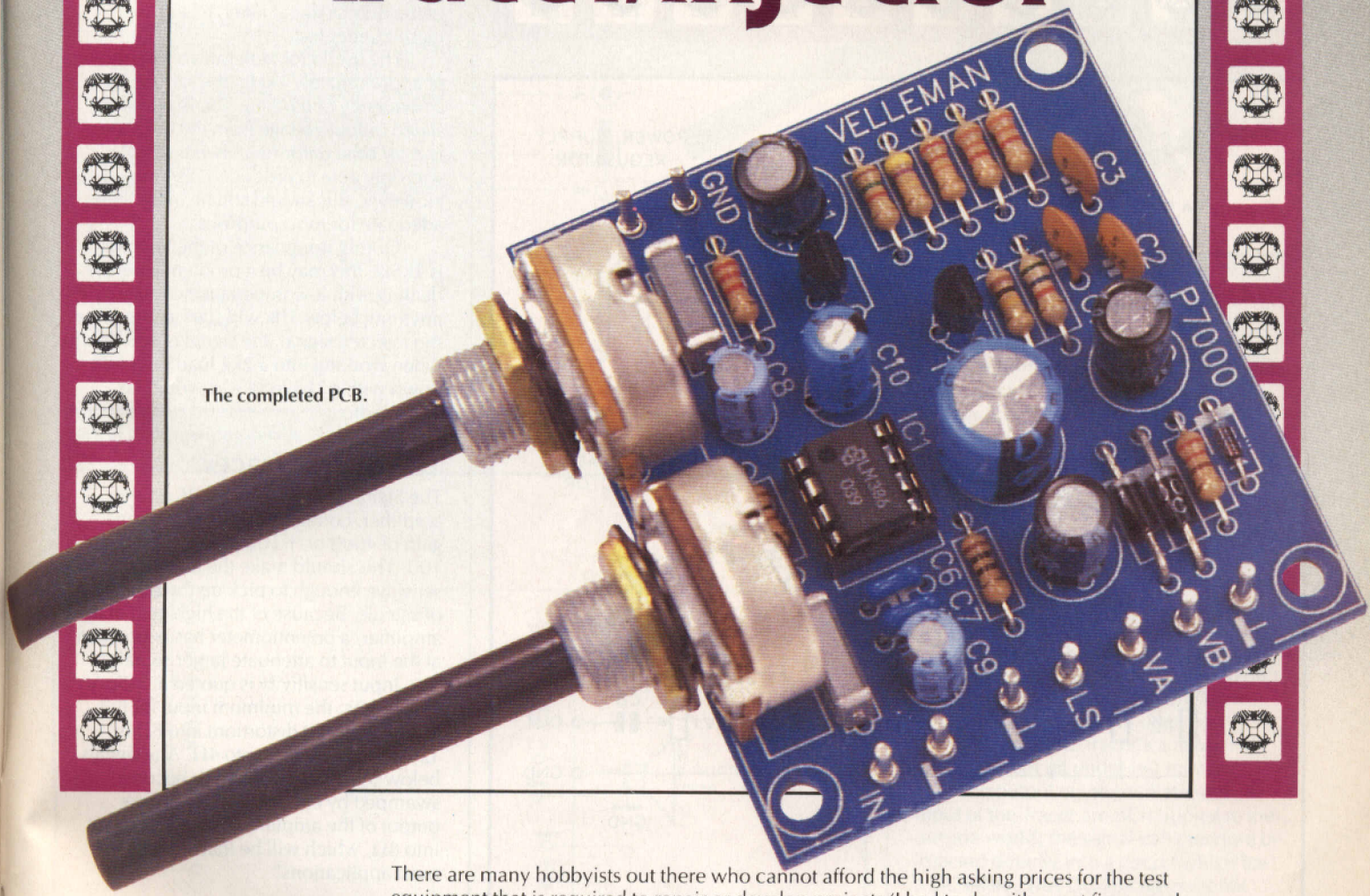
Text by Alan Williamson

K7000 Signal Tracer/Injector



The completed PCB.

There are many hobbyists out there who cannot afford the high asking prices for the test equipment that is required to repair or develop projects (I had to do with a wet finger and a £5 meter for a few years!).

A Signal Tracer/Injector is a very useful and low-cost piece of test equipment that will help to find faults quickly in low-frequency analogue equipment. It will also be an invaluable addition to anyone's toolbox – and more importantly, it won't break the bank.

FEATURES

- ★ Low-Cost
- ★ 1kHz Sine Wave Oscillator (Signal Injector)
- ★ Battery or Mains Operation
- ★ 40dB Gain Amplifier with 1W Output (Signal Tracer)

APPLICATIONS

★ Servicing Audio Equipment – easy fault location
★ 'Hands-On' Learning
★ Can be used as simple amplifier/oscillator (e.g. for Morse code practice) – or just as a general-purpose amplifier.

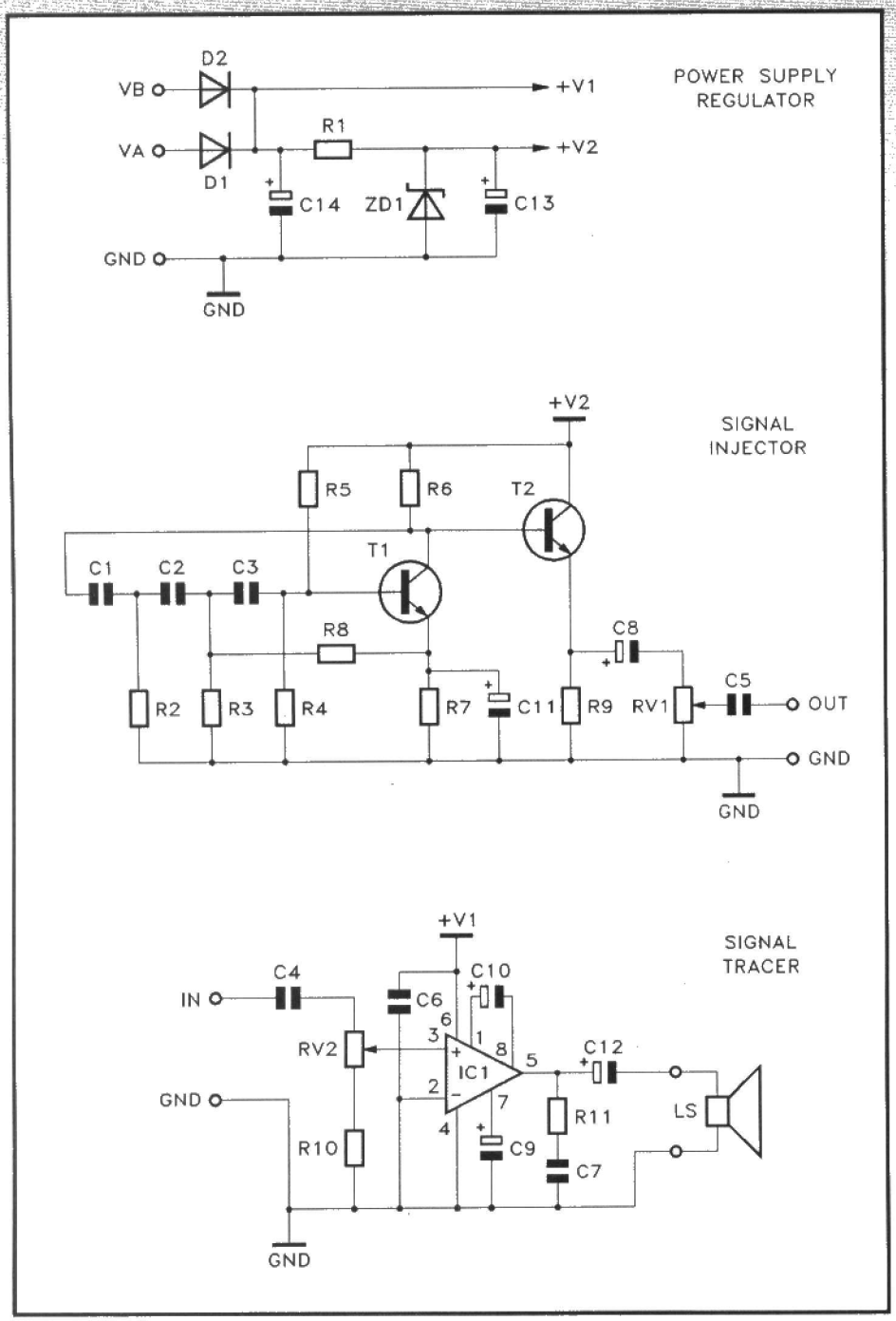


Figure 1. Signal Tracer/Injector circuit diagram.

Basically, the circuit under test is 'injected' with a recognisable audio signal, the progress of which is noted through the various stages of the circuit.

Circuit Descriptions

(Refer to Figure 1.)

The Signal Injector

The Signal Injector is a simple phase-shift oscillator, the essential part of which is the 'ladder network', based around C1 to 3, R2 and R3; these components form the positive feedback loop for TR1, causing the circuit to oscillate. The output of the oscillator is buffered by emitter follower TR2, which must be present to prevent 'loading' of the oscillator circuit. Potentiometer RV1 allows attenuation of the output signal level, to suit the circuit under test.

The oscillator generates a sine wave of approximately 1kHz (the sample has a frequency of 657Hz). The maximum stated output voltage from the oscillator is 2·5V rms; unfortunately the sample was only able to produce 1·56V rms. However, this should still be more than adequate for most purposes.

Output impedance of the Injector is 1k5Ω; this may be a problem when dealing with low impedance circuits – anything below 10k will start to attenuate the injected signal (the signal is 3dB down when working into a 2k2 load, and 6dB down with a 1k5 load – as would be expected).

The Signal Tracer

The Signal Tracer is an LM386 power amplifier, configured to give a voltage gain of 40dB or, if you prefer, a gain of 100. This should make the amplifier sensitive enough to pick up the smallest of signals. Because of the high gain of the amplifier, a potentiometer has been fitted at the input to attenuate larger signals.

Input sensitivity is quoted at 3·5mV to 10V rms; the minimum input for full output (without distortion) into 8Ω is 12·7mV and 15·5mV into 4Ω. Any signals below 3·5mV would start to become swamped by excessive noise. Power output of the amplifier is over half a watt into 8Ω, which will be loud enough for most applications!

Power Supply Options

The power supply is a simple zener regulated type. If the circuit is to be powered from a battery source, connect the positive terminal of the battery to either of the pins on the PCB marked VA or VB and the negative connection to one of the ground terminals, most of which are marked with a 'ground' symbol. This arrangement is shown in Figure 2. If a mains supply is to be used, the wiring diagram of Figure 3 should be followed. In this case, a 7V to 9V centre-tapped transformer would be required (eg. YN15R, 9-0-9V). Connect the centre tap to a ground terminal on the PCB; the other two transformer secondary leads are connected

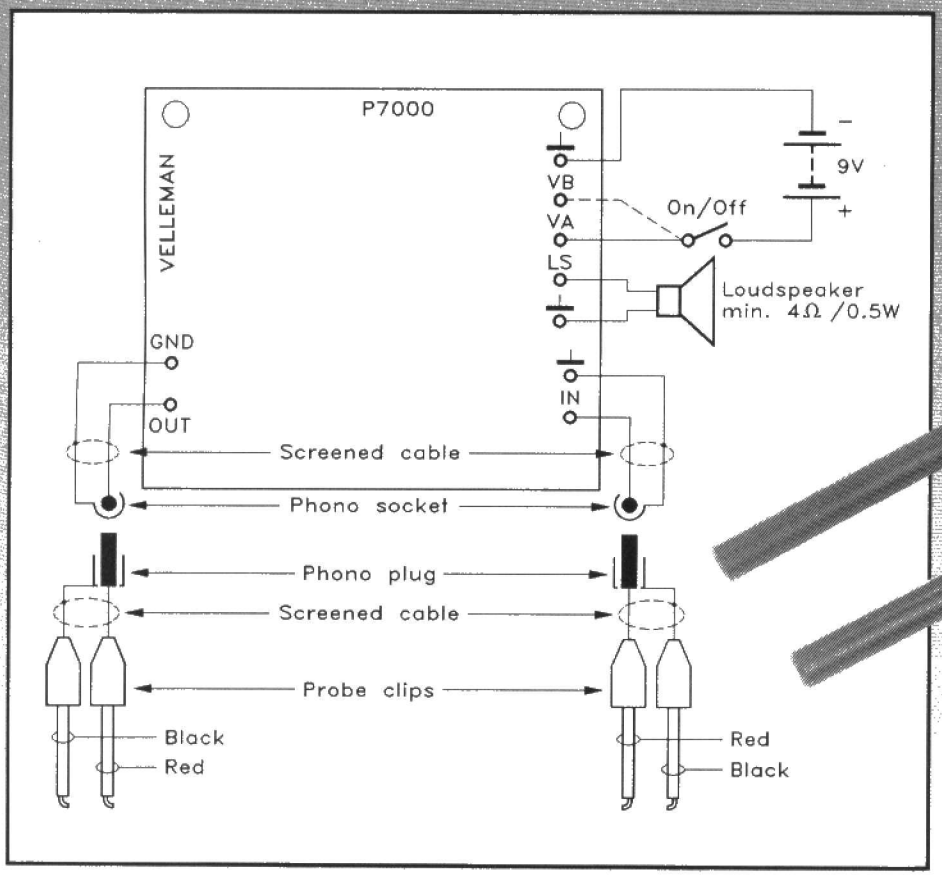


Figure 2. Battery wiring details.

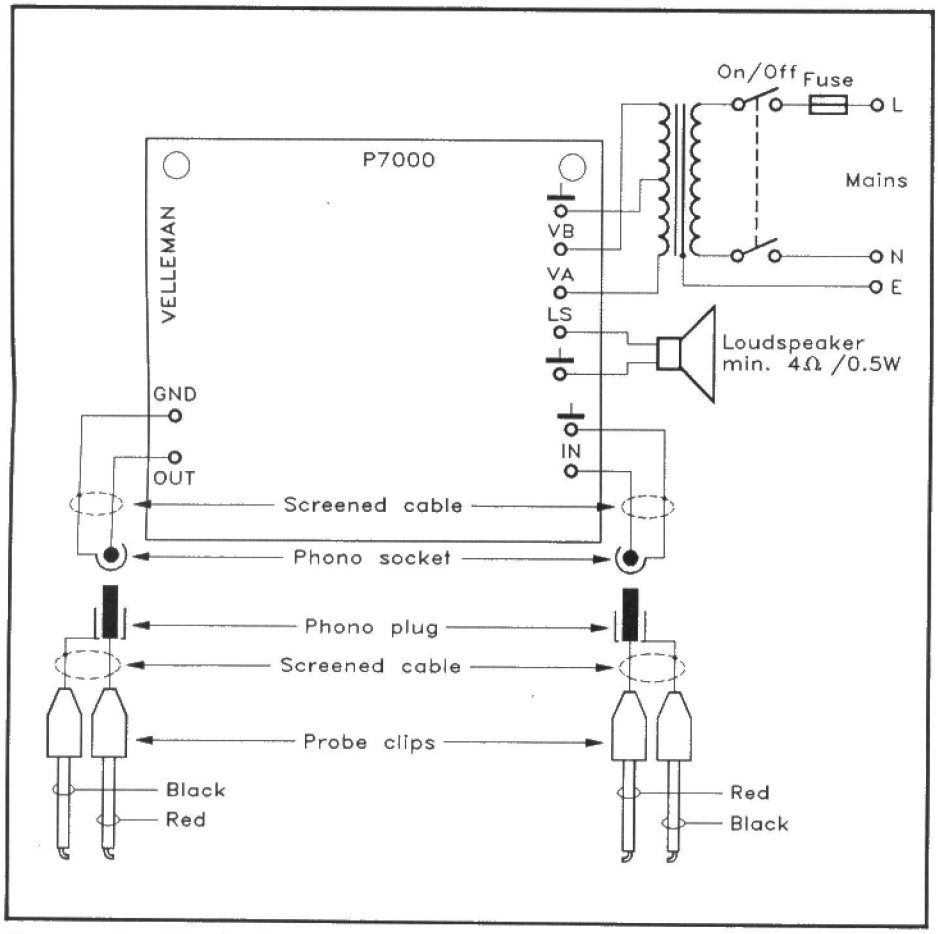


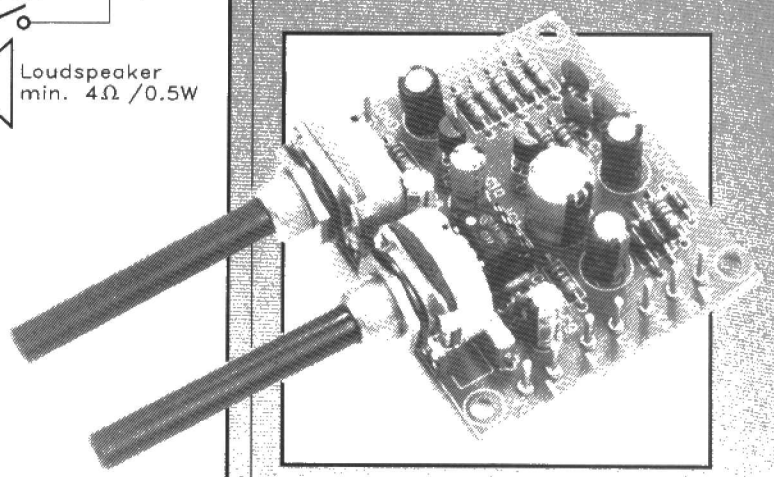
Figure 3. Mains wiring details.

to VA and VB. The usual safety precautions apply when using mains electricity; a double-pole switch must be used.

Total current consumption of the sample, under full load conditions, is 170mA.

Building the Kit

A comprehensive instruction booklet is supplied with the kit, along with a component identification leaflet. The kit contains all the PCB components required for the high-quality fibreglass board.



Using the Signal Tracer/Injector

When repairing low-frequency analogue equipment, a Signal Tracer/Injector will speed up the fault-finding process enormously. For example, if you have a faulty amplifier and don't know where the fault is, divide the circuit in two (not literally!) and connect the Signal Tracer at that point. Inject a signal into the input; if the Tracer is unable to detect the signal, divide the circuit in two again and move its connections to this new point of the circuit. In this manner, faults can be traced fairly quickly.

Don't forget to adjust the attenuators of the Tracer and Injector to minimum before injecting a signal, otherwise overloading of the Tracer's amplifier and/or the circuit under test may occur.

The output of the oscillator and the input of the Tracer are AC-coupled to the outside world; the signal can therefore be injected directly into a circuit which has a DC offset. This DC voltage must not exceed the working voltage rating of the capacitor.

A way around the problem of low-impedance circuits is to couple the output of the oscillator to the input of the amplifier; the signal can then be injected into the circuit under test. However, this obviously means that a second amplifier would then be required to 'trace' the signal.

Because the output of the power amplifier is fitted with a polarised electrolytic capacitor, the signal can only be injected into a circuit which is at ground potential; alternatively, the output capacitor could be replaced with a non-polarised type.

Happy Hunting!

SIGNAL INJECTOR/TRACER PARTS LIST

RESISTORS		
R1	220Ω	1
R2,3	3k3	2
R4	22k	1
R5	100k	1
R6	5k6	1
R7	1k5	1
R8	470k	1
R9	2k2	1
R10	100Ω	1
R11	10Ω	1
RV1	4k7 Pot Lin	1
RV2	47k Pot Lin	1
CAPACITORS		
C1-3	10nF Ceramic	3
C4,5	100nF Poly Layer	2
C6,7	100nF Monores	2
C8,9	1μF Electrolytic	2
C10	47μF Electrolytic	1
C11-13	100μF Electrolytic	3
C14	470μF Electrolytic	1
SEMICONDUCTORS		
D1,2	1N4000 Series Diodes	2
ZD1	7V5 Zener Diode	1
TR1,2	BC547	2
IC1	LM386	1
MISCELLANEOUS		
	DIL Socket 8-Pin	1
	PCB Pins	9
	PCB	1

The Maplin 'Get-You-Working' Service is available for this project.

The above items (excluding Optional) are available in kit form only.

Order As VE62S (Velleman Kit K7000) Price £10.95.

Please note that the PCB is not available separately.

OPTIONAL PARTS LISTS

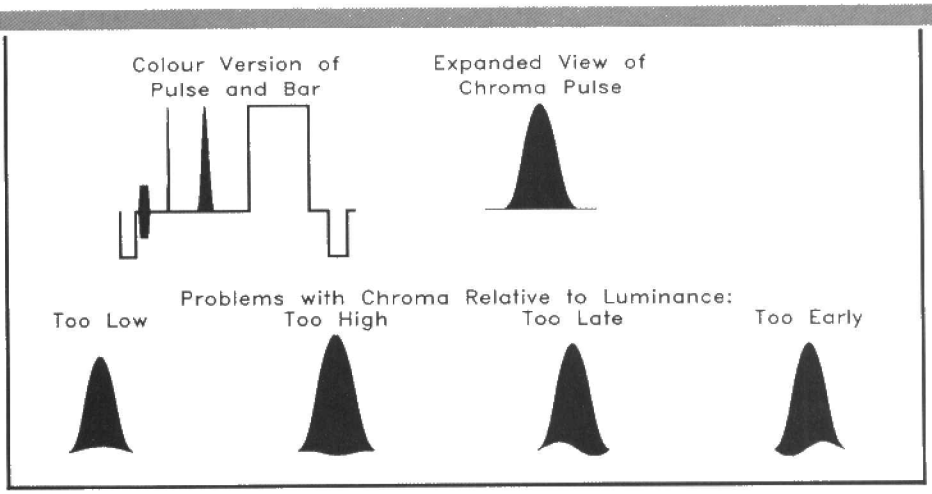
For Mains Power Supply		
9-0-9V Transformer 250mA	1	(YN15R)
20mm 50mA Quick-blow Fuse	1	(WR93R)
20mm Safuseholder	1	(RX96E)
Fuseholder Insulating Boot	1	(FT35Q)
Red Neon Rocker	1	(YR68T)
Min. Black Mains 3A cable	As required	(XR01B)
5R2 Cable Grommet	1	(LR48C)
13A Rubber Mains Plug	1	(HL58N)
2A Mains Fuse	1	(HQ31J)
Isotag M3	1	(LR64U)
Steel Screw M3 × 16mm	2	(JY24B)
Steel Nut M3	2	(JD61R)
Isoshake M3	3	(BF44X)
For Battery Power Supply		
PP3 Battery Clip	1	(HF27E)
Alkaline PP3 Battery	1	(FK67X)
or		
PP6 Battery	1	(FM03D)
Ideas for Boxes		
PX-3 ABS Box	1	(YU54J)
or		
D-009 Project Box	1	(ZB02C)

Alternatively, you can use the presentation case in which the kit was supplied.

Optional Hardware		
Black Phono Plug	1	(HQ54J)
Red Phono Plug	1	(HQ58N)
Chassis Phono Socket	2	(YW06G)
Probe Clips	2 Pairs	(HF21X)
Single Core Screened Cable Black	As required	(XR12N)
Low-Z 778 Speaker	1	(YW53H)
Blue Knob	1	(FE74R)
Red Knob	1	(FE76H)
Insulated Spacers M3 × 10mm	1 Packet	(FS36P)
Stick-on Rubber Feet Large	1 Packet	(FW38R)

Video Systems continued from page 61.

This consists of a luminance pulse (1 or 2μS half-amplitude duration) of 50% peak white level, with a 100% burst of chroma superimposed. The composite pulse appears on the waveform monitor as a 100% raised cosine envelope 'filled' with subcarrier, and having a flat base. This is important, since only if luminance and chrominance match exactly in timing and level will the base of the pulse appear flat. This composite pulse, then, is extremely sensitive to both level and timing differences between luminance and chroma. Many types of equipment handle luminance and chrominance separately and this test waveform is the only one that will allow such equipment to be accurately adjusted for Y-C delay matching. Most pre-recorded alignment tapes for professional VTRs have a few minutes of this waveform recorded, though again only the more expensive test generators can produce it. Actual measurement of a luminance/chroma gain or delay error is quite difficult without a specific piece of equipment. This test set separates and recombines luminance and chroma and allows calibrated delays and attenuators to be switched into one path. If the output waveform is adjusted to look as nearly correct as possible, then the sum of the delays and gains will be equal to the errors in the original signal.



The other important colour test waveform is the 'modulated staircase'. A luminance staircase waveform, or sometimes a ramp, has a constant level of subcarrier added to it. This signal is then used to examine the handling of subcarrier over the range of possible luminance values. Of course, both the level and phase of the subcarrier should remain constant but many forms of distortion will cause these values to vary. These errors are 'differential gain' and 'differential phase' respectively, and both this test signal and a fairly good vectorscope are necessary to measure them accurately. Many direct colour VTRs have user adjustments to minimise differential gain and phase errors and this is the waveform used for this purpose.

A number of other test signals exist, largely aimed at specific types of equipment. Various 'illegal' types of chroma, for example PAL-switched U and PAL-unswitched V are useful in adjusting PAL decoders, and chroma ramps both YUV and coded can be used to check digital video equipment. Many test generators allow Y, U, V, burst and even sync to be turned off independently, and it is surprising how often such unnatural and 'illegal' signals turn out very useful in troubleshooting.

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The full range of Velleman kits is available from Maplin Electronics, official appointed U.K. agents, including the Velleman K4000 (VE99H £499.95 [H]), high performance valve power amplifier, (featured above). Prices of Velleman kits start from as low as £7.45 and all kits are manufactured to the same high standards and quality.

See the full range of Velleman kits in the 1992 Maplin Catalogue £2.75, or by post £2.95 (CA09K), or visit your local Maplin store. Credit Card Hotline 0702 554161. Mail Order to: P.O. Box 3, Rayleigh, Essex SS6 8LR.

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